THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. I.

No. XI.—NOVEMBER, 1914.

ORIGINAL ARTICLES.

I.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, B.A., F.G.S.

(*Continued from the August Number, p. 347.*)

(PLATE XXXV.)

A SMALL group of English *Membraniporæ* is strongly characterized by the possession of interstitial avicularia having one end raised into a smooth hood. No described species seems to possess such avicularia, except perhaps the form figured by d'Orbigny as *Membranipora concatenata*.[1]

Membranipora cucculligera, sp. nov. (Pl. XXXV, Figs. 1, 2.)

Zoarium unilaminate, adherent.

Zoœcia fairly large, very slightly pyriform, areas oval, average length ·5 to ·6 mm., breadth ·38 to ·4 mm.; side walls fairly thick, slightly overarching.

Oœcia occurring freely, small, rather shortly globular, with slightly concave free edges lying well back from the margin of the area, the side wall of which is very thin beneath them (Fig. 2).

Avicularia only of the type characteristic of the group, from one-third to one-half the area of the surrounding zoœcia; the lower part is pyriform and embraces the lower half of the aperture in a horizontal plane; the upper part is raised as a hood, the free edge of which rises at a steep angle and is marked off by a shallow furrow; they are fragile, but even badly damaged specimens generally suggest their nature at once.

This species is known only in the zone of *M. cor-anguinum* in Hants and Kent, where it occurs regularly.

Membranipora vestigialis, sp. nov. (Pl. XXXV, Figs. 3, 4.)

Zoarium unilaminate, adherent.

Zoœcia elliptical, wide in the middle, but tapering a good deal at the ends, with very low and very thin side walls looking like mere traces of a more robust form; average length of area ·45 to ·6 mm., breadth ·3 to ·35 mm.

Oœcia numerous and fairly robust, small, helmet-shaped, but slightly rectangular in ground plan, the free edge coinciding with the outline of the area.

[1] Pal. Crét. Franç., tome v, pl. 729, fig. 6.

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[1] Pal. Crét. Franç., tome v, pl. 729, fig. 6.

Avicularia only of the type characteristic of the group, about one-third the size of the zoœcia, numerous, robust, and very prominent, distributed irregularly, but with a strong tendency to succeed oœcia.

This species occurs very sparingly in the zone of *M. cor-anguinum* in Hants and Kent and in the zone of *O. pilula* in Sussex. Above the latter zone the group is entirely unrepresented in my collection until we come to the Trimingham Chalk.

MEMBRANIPORA PRÆCIPUA, sp. nov. (Pl. XXXV, Figs. 5–7.)

Zoarium unilaminate, adherent.

Zoœcia large with fairly thick side walls overhanging very slightly; areas elliptical, average length from ·65 mm. upwards, breadth from ·35 mm. upwards.

Oœcia abundant but delicate, slightly globular, the free edge coinciding with the outline of the area, the side wall of which is exceedingly thin beneath them.

Avicularia of two types—

1. Interstitial, of the type characteristic of the group, nearly as large as the zoœcia and tending to introduce new rows of zoœcia; the hood is straight or even slightly concave in outline at the upper end, and has a free edge embracing the upper half of the aperture and then curving round and backwards to a point of attachment on the outer margin; there are distinct traces of a bar across the aperture just below the hood.

2. Vicarious, long drawn out and very gently curving, extreme instances of the hour-glass type with traces of a bar across the lower end; they are the most graceful and delicate objects that I have met, and the figures do not do them anything like justice.

The vicarious avicularia are extremely capricious in occurrence; the interstitial ones are also rather capricious, but it is very rare for any zoarium of decent size which suggests this species by the dimensions of its zoœcia not to show at least one recognizable, even if damaged, avicularium of this type (Figs. 5, 7).

This species, which is apparently confined to the Trimingham Chalk, seems clearly a descendant or near relation of *M. cucullígera*.

MEMBRANIPORA SACERDOTALIS, sp. nov. (Pl. XXXV, Figs. 8–10.)

Zoarium unilaminate, adherent.

Zoœcia markedly pyriform with slender slightly overarching side walls and narrowly elliptical areas of average length ·5 mm. and breadth ·25 to ·3 mm.; in early stages the zoœcia tend to be broadly elliptical (Fig. 8).

Oœcia very numerous but very delicate, long, and narrow, in ground plan widest at the upper end and tapering gradually downwards, markedly bottle-necked.

Avicularia of two types—

1. Interstitial, of the type characteristic of the group, small, long, and narrow, with the hood very well developed and resembling a monkish cowl, and a bar across the aperture sometimes preserved; the aperture almost invariably faces the centre of the zoarium, the reversed specimens seen in Fig. 10 being quite abnormal. This

type is exceedingly erratic in occurrence; in the very large zoarium from which Fig. 9 is taken they are not as numerous as one per 100 zoœcia, while Figs. 8 and 10 show how numerous they can be in exceptional cases.

2. Sub-vicarious, of the hour-glass type, very narrow, with the covered centre much drawn out and the open ends short and rounded; very rarely a bar across the lower end is preserved. Avicularia of this type are always present in abundance.

The species appears to be confined to the Trimingham Chalk.

EXPLANATION OF PLATE XXXV.

(All figures × 12 diams.)

Fig.				
1.	*Membranipora cuculligera.*	Zone of *M. cor-anguinum.*		Wallers Ash, Hants.
2.	,,	,,	,,	Gravesend.
3.	,, *vestigialis*	,,	,,	Micheldever, Hants.
4.	,,	,,	,,	Gravesend.
5.	,, *præcipua.*	Trimingham.		
6.	,,	,,		
7.	,,	,,		
8.	,, *sacerdotalis*	,,		
9.	,,	,,		
10.	,,	,,		

II.—Fossil Insect in Amber.

On *Stenurothrips succineus*, gen. et sp. nov., an interesting Tertiary Thysanopteron.

By Richard S. Bagnall, F.L.S., F.E.S.

(PLATE XXXVI.)

THE thrips described herein was submitted to me by Professor Branca of the Geologisch-Palaeontologisches Museum, Berlin, and is one of a small collection of three examples in Baltic Amber. The genus is curious on account of the abnormal tube-like development of the tenth abdominal segment, which, however, is open ventrally for its entire length. In the form of the antennæ, so far as can be ascertained from the single example and the structure of the wings, *Stenurothrips* would seem to show affinity with the Neotropical genus *Heterothrips*, and for the present I regard the genus as falling in the Heterothripidæ.

In the generic description I have stated that there is a cross-vein connecting the two longitudinal veins of the fore-wing near the basal third. In this example I *think* I can discern this cross-vein, which is shown somewhat markedly in the figure, but it is open to some doubt. In another species of the same genus now before me, and chiefly separated from the present species by the more minute spines of the fore-wing, the wings are spread out, and this cross-vein is distinctly discernible.

Whilst I have been able, by various lighting arrangements, to obtain a close detailed report of the upper surface, it has been impossible to make out the mouth-parts, the legs, which are tucked under the body, the basal part of tube ventrally, etc., on account of a thick milky cloudiness, which, in a lesser degree, also somewhat

obscures the dorsal surface of the abdominal segments 8, 9, and base of 10, so that it is impossible to describe the arrangement of bristles, shown in the figure as springing from segment 9 with absolute accuracy. The angle of the antennæ makes it impossible to gauge the relative lengths of segments.

Order THYSANOPTERA.

Sub-order TEREBRANTIA.

Family HETEROTHRIPIDÆ, Bagnall.

Genus STENUROTHRIPS, nov.

♀ Head transverse, about as long as prothorax. Antennæ nine-jointed, the first four joints stouter than the succeeding five.

Prothorax transverse, two prominent bristles at each hind angle; mid-lateral pair well developed. Pterothorax well developed. Wings long, fore-wing with two longitudinal veins each uniting with the ring-vein near apex; apparently a cross-vein uniting the longitudinal veins near basal third. Costa and both veins set for whole length with setæ.

Abdomen elongate-ovate, with tenth segment abnormally produced, very elongate, cylindrical, open ventrally for entire length, and longer than the length of head and prothorax together. Segment 9 furnished with long bristles, and 10 with a series of setæ before apex. Ovipositor presumably long and straight.

Type: *Stenurothrips succineus*, mihi.

Of living Thysanoptera this form undoubtedly comes near *Heterothrips*, a Neotropical genus, but is strikingly distinguished by the abnormal development of the tenth abdominal segment, the tubiform appearance suggesting a Tubuliferon.

We have noticed several forms distinguished by a similar development, notably *Panchætothrips*, a Heliothripid-like form, distinguished by the form of the explanate margins of abdomen and produced pleurites, and the tube-like tenth abdominal segment, in which there is exhibited a tendency for the ventral opening to close. In this form the ovipositor is styliform and but poorly developed. In *Dinurothrips*, Hood, and *Macrurothrips*, Vuillet, the tenth segment is also strikingly developed.

STENUROTHRIPS SUCCINEUS, sp. nov.

Length about 1·8 mm., breadth of mesothorax 0·35 mm., length of tenth abdominal segment about 0·35 mm.

Head transverse, about 0·75 as long as broad, and as long as or a little longer than the prothorax. Cheeks sub-parallel, dorsal surface near base faintly striate. Eyes large, moderately closely facetted and apparently pilose; greatest dorsal length equal to about 0·75 the total length of head, and space between eyes about 0·4 the greatest breadth across them. Ocelli moderately large, well separated, posterior ones close to the inner margin of eyes; a pair of minute interocular setæ present. Two pairs of rather long backwardly directed setæ on a line behind eyes, practically equidistant, the

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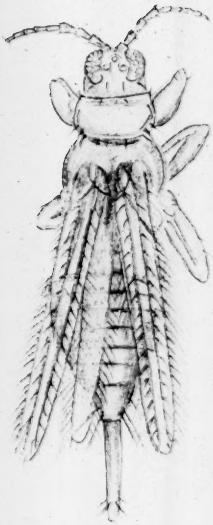

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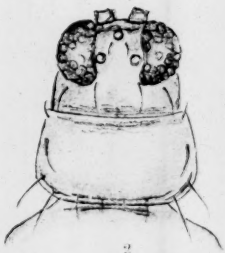

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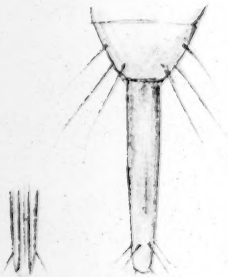

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STENUROTHRIPS SUCCINEUS *gen. et sp. nov.*

From Baltic Amber.

inner pair being on a slightly higher plane, one near hind angle of each eye. Antennæ nine-jointed, the breadth of the first four joints, which are finely ringed, being noticeably greater than any of the succeeding and 2–4 sub-equal; joints 5–7 fusiform and apparently sub-equal in length.

Prothorax transverse, nearly twice as broad across posterior third as long through middle; anterior angles obtuse, the hind angles broadly rounded. Surface, anteriorly at least, faintly transversely striate. Each hind angle furnished with two long bristles, about 0·6 the length of the prothorax; a mid-lateral pair backwardly (and slightly inwardly) directed and about 0·45 the length of the prothorax. A series of at least two pairs of postero-marginal setæ.

Pterothorax well developed, much broader than prothorax but not quite as broad as the abdomen at broadest. Wings long, about ten times as long as broad near middle, reaching to about the middle of the tenth abdominal segment, apically somewhat pointed; two distinct longitudinal veins running for the entire length of fore-wing, apparently connected by a cross-vein at about the basal third, and each uniting with the ring-vein near tip. Costa and longitudinal veins uniformly set with moderately long stout setæ, the costa with approximately 45, upper vein 23, and the lower vein 18; a single seta set near apex of wing, just beyond fore-vein but not on it. Setæ as long as or longer than 0·35, the breadth of wing near middle.

Abdomen — excluding segment 10 — elongate-ovate, the ninth segment narrowing to base of 10, which latter is exceptionally elongated, a little longer than the length of the head and prothorax together; ventrally open for its entire length and furnished with a series of setæ just before apex. Ninth segment furnished with four postero-marginal bristles, of which the outer pair is apparently longer than the inner and about 0·5 the length of the tenth segment; also furnished with another and shorter dorsal, dorso-lateral, or lateral pair on a higher plane.

EXPLANATION OF PLATE XXXVI.

FIG. 1. *Stenurothrips succineus*, gen. et sp. nov. × 35.
,, 2. ,, ,, Head and prothorax. × *c.* 70.
,, 3. ,, ,, Ninth and tenth abdominal segments. × 70.
,, 4. ,, ,, Underside of tip of tenth abdominal segment. × 70.
,, 5. ,, ,, Right fore-wing. × *c.* 50.

Formation and locality: from Tertiary Lignite Deposits, shores of the Baltic, extending from Dantzig to Memel, etc.

III.—The Principle of Saturation in Petrography.

By S. J. Shand, D.Sc., F.G.S.,
Professor of Geology, Victoria College, Stellenbosch, South Africa.

In a recent number of this journal[1] I advocated the systematic employment of a certain criterion in connexion with the classification and nomenclature of igneous rocks, that criterion being the 'saturated' or 'unsaturated' character of the minerals constituting

[1] Geol. Mag., November, 1913, pp. 508–14.

a given rock. The terms *saturated*, *unsaturated*, and their derivatives *oversaturated*, *undersaturated*, and *partsaturated*, were not used in a strict chemical sense, but in a special mineralogical sense which was fully explained.

Mr. Alexander Scott[1] has criticized my proposal from a theoretical standpoint, and rejects it, but omits to say whether he prefers the 'silica-percentage' type of petrography which it was my aim to supplant. It was not my intention, in writing the paper in question, to offer a complete solution of the most vexed question in petrography, but only to contrast the efficacy of the 'saturation' criterion with that of the silica-percentage as the basis of a descriptive classification. I showed, to my own satisfaction at least, that the former has various advantages over the latter, its easy applicability to the majority of rocks being only one of them. He, however, raises the whole question of the classification of igneous rocks, and subjects my proposal to criticisms which are equally applicable to all propositions for rock classification which have ever been made.

Mr. Scott dreams of a classification which shall "correlate rocks not only of similar chemical composition but also with similar cooling-'histories'". So do we all, and we shall all wish with him success in the search for it. But in the meantime such a classification eludes us, and we must live in a cottage until the palace is ready. It is poor work to destroy without creating, so until he is able to give us something better in exchange for it, we shall beg Mr. Scott (who is only following in the footsteps of Cross and many another) not to pull our present refuge down about our ears. As for my own little contribution, which started this discussion, I regard it in the light of a new beam inserted in the temporary structure in the place of one which, in my judgment, was defective; I have not sought to lay the foundation of a new edifice. When the ultimate classification of rocks is forthcoming, my suggested groupings will disappear from currency (should they ever attain it); nevertheless, I have sufficient confidence in their value to believe that they will not be found irreconcilable with the fundamental principles of that classification of the future.

When one approaches the subject of rock-classification, it is very important to have a clear idea of the aim of classification in general. John Stuart Mill's views on the subject cannot be surpassed for clearness, and the following extracts from his *System of Logic* seem to me to be so especially pertinent to the present subject that I offer no apology for quoting them in a petrographical discussion.

"Classification . . . is a contrivance for the best possible ordering of the ideas of objects in our minds; for causing the ideas to accompany or succeed one another in such a way as shall give us the greatest command over our knowledge already acquired, and lead most directly to the acquisition of more. The general problem of Classification, in reference to these purposes, may be stated as follows: To provide that things shall be thought of in such groups, and those groups in such an order, as will best conduce to the remembrance and to the ascertainment of their laws.

[1] GEOL. MAG., July, 1914, p. 319.

"The ends of scientific classification are best answered when the objects are formed into groups respecting which a greater number of general propositions can be made, and those more important, than could be made respecting any other groups into which the same things could be distributed. The properties, therefore, according to which objects are classified should, if possible, be those which are causes of many other properties; or, at any rate, which are sure marks of them. Causes are preferable, both as being the surest and most direct of marks, and as being themselves the properties on which it is of most use that our attention should be strongly fixed. But the property which is the cause of the chief peculiarities of a class is unfortunately seldom fitted to serve also as the diagnostic of the class. Instead of the cause, we must generally select some of its more prominent effects, which may serve as sure marks of the other effects and of the cause.

"A classification thus formed is properly scientific or philosophical, and is commonly called a Natural, in contradistinction to a Technical or Artificial, classification or arrangement. The phrase Natural Classification seems most peculiarly appropriate to such arrangements as correspond, in the groups which they form, to the spontaneous tendencies of the mind, by placing together the objects most similar in their general aspect; in opposition to those technical systems which, arranging things according to their agreement in some circumstance arbitrarily selected, often throw into the same group objects which in the general aggregate of their properties present no resemblance, and into different and remote groups others which have the closest similarity. It is one of the most valid recommendations of any classification to the character of a scientific one, that it shall be a natural classification in this sense also; for the test of its scientific character is the number and importance of the properties which can be asserted in common of all objects included in a group; and properties on which the general aspect of the things depends are, if only on that ground, important as well as, in most cases, numerous."

The properties upon which the general aspect of a rock (as distinguished from a rock-body) depends are its mineral constitution and its structure (texture); hence it is not surprising that these properties have from the first been seized upon as being most suitable for the formation of groups. Whatever views one may hold as to the general utility of a classification which is based upon these properties, there can be no question about its being a perfectly 'natural' one, and therefore, according to Mill, a scientific one.

But a school has arisen in later years which demands more regard for chemical composition in our system, and which will not be satisfied with the stock reply that "mineral constitution is a function of chemical composition". Classifications have accordingly been evolved in which mineral constitution is subordinated to ultimate composition, expressed either in molecular ratios or sometimes in mere bald percentages. After much controversy it has generally been conceded that there is reason in both views, and consequently in many recent attempts at classification it has been sought to combine chemical with mineralogical data.

I am in full agreement with Mr. Scott when he states that "These two factors . . . the chemical and mineralogical composition, are the only ones we have for a basis in classification", but when he goes on to assert that they "must be correlated", then I stop short to ask him how he proposes to accomplish it. It is so easy to say "let it be done", so difficult to do it! And Mr. Scott gives us no assistance whatever.

Here is the crux of the whole matter. Anybody who can produce a system in which chemical and mineralogical characters shall be correlated in a satisfactory manner will have solved the great problem of petrography. For myself, having studied the attempts that have been made up to the present time to correlate these properties of rocks, and having myself made very numerous and laborious efforts to accomplish the feat, I have become convinced that nothing is to be gained, but much to be lost, by juggling with these two factors in a hybrid classification.

How can one talk of correlating mineral and chemical composition when one of the commonest of rock minerals shows such a range of composition as the following?—

SiO_2	from	38·41	to 50·08
Al_2O_3	,,	7·07	,, 17·58
Fe_2O_3	,,	0·00	,, 12·42
FeO	,,	0·57	,, 22·22
MgO	,,	2·54	,, 16·31
CaO	,,	9·55	,, 13·75
Na_2O	,,	0·58	,, 3·18
K_2O	,,	0·00	,, 2·18
TiO_2	,,	0·00	,, 10·31

The figures are extracted from Iddings,[1] and the various materials to which the analyses refer are all described as 'hornblende'.

Nephelite is a very definite species to the observer at the eyepiece of the microscope, yet it may hold from 14 to 18 per cent of soda, and from 1 to 7 per cent of potash. The black or brown garnet, which the microscopist identifies as melanite, may range in composition from andradite to schorlomite, and may hold 10 per cent of MnO or Al_2O_3, or 20 per cent of TiO_2, which can only be detected by chemical analysis.

It is clearly impossible for us to isolate and to analyse separately every constituent of a given rock; hence I say that until we discover a means of deducing the chemical composition of such minerals as these from their optical properties, with as much certainty as is attainable in the case of the felspars, no satisfactory expression of the chemical composition of a rock can be made in terms of minerals, or vice versa.

The question whether mineral and chemical composition can be correlated in a satisfactory way is surely answered by the failure of every attempt to perform the operation. Osann's method[2] of building a chemical superstructure upon a mineralogical basis is severely condemned by the American chemical school of petrography,[3] and has not found favour in Britain or France. Iddings, in his most recent work,[4] employs a simple mineral-textural method of grouping and appends to each group a discussion of the chemical composition of the rocks comprised within it. But to do this he must practically make a separate statement of composition for each rock; no general

[1] *Rock Minerals*, 1911.
[2] Tschermaks Min. Pet. Mitt., xix et seq.
[3] Cf. Cross in *The Quantitative Classification of Igneous Rocks*.
[4] *Igneous Rocks*, vol. ii, 1913.

statements can be made, hence there is no correlation. Hatch[1] effects a classification by employing the mineral constitution, as expressed by felspars and felspathoids, and the silica-percentage as abscissa and ordinate in a cross-classification. It is obvious that the method does justice neither to chemistry nor to mineralogy, since all the constituents are not regarded; and furthermore it is easy to show that such a classification makes little advance upon a simple linear classification by felspars alone or by silica-percentage alone, because when the felspars are abundant they largely determine the silica-percentage of the rock. This means that in many cases the two co-ordinates are not independent of each other, hence the purpose of a cross-classification is not attained.

Winchell[2] has recently proposed a classification on three co-ordinates. One of these is mineral constitution, and is chiefly concerned with the kind of felspar present. The second is geological occurrence. The third co-ordinate is the alkaline, peralkaline, or alkalcic (i.e. alkali-calcic) character of the rock as determined (by inspection) from consideration of the relation between alkalies, silica, lime, etc., in all the minerals present. Thus the peralkaline group consists of rocks containing felspathoids; the alkaline group contains chiefly alkali-felspars and alkali-pyroxenes, etc. The third co-ordinate therefore expresses in a rough way the ratio of alkalies to silica, thus—

Alkaline = high alkalies, high silica.
Peralkaline = high alkalies, moderate or low silica.
Alkalcic = low alkalies, moderate or low silica.

This classification consequently affords only a very incomplete and purely qualitative expression of chemical composition.

There are many other classifications which might be passed in review, but it would be waste of ink, for it is matter of common knowledge that, whatever their merits may be, no one of them has ever succeeded in so correlating mineralogy with chemical composition as to satisfy the two opposed schools of petrography. Personally, I have renounced the attempt. I believe it to be impossible. But that does not mean that, in my view, one class of data must be neglected. I believe that both chemical and mineralogical classifications are necessary in order to "give us the greatest command over our knowledge already acquired, and lead most directly to the acquisition of more". And instead of yearning for the unattainable, I should like to see all petrographers trying to agree upon *one* chemical classification and *one* mineralogical classification to meet our present needs. They might not be final, but what of that? They would at least give us a common language in which to compare and record our observations. Apothecaries' weight, based on a grain of corn and other primitive standards, served science well until the metric system was introduced. Fahrenheit and Centigrade thermometers registered the observations which led to the conception

[1] *Text-book of Petrology*, 1909, 1914.
[2] *Journal of Geology*, xxi, 1913.

of the Absolute scale of temperature. If Mr. Scott's arguments were extended to other things besides rock-classifications, nobody would use a lamp, because it is far inferior to daylight, or a taxicab, because it is not an aeroplane.

Although I advocate separate chemical and mineralogical classifications for rocks, it does not follow that the mineralogical classification must be devoid of chemical significance. It must, indeed, divest itself of all attempts to express the percentage composition of rocks in terms of oxides or arbitrarily chosen molecules, but in the act of stating the proportions of various minerals in a rock we unavoidably make some sort of a statement of its composition. Furthermore, the investigation of the proportions which the constituent minerals bear to one another involves the recognition of eutectic proportions, where such exist. If eutectic ratios are to play a part in petrographic system, it is in the mineralogical classification that they will find expression, not in that which deals with ultimate chemical composition. And if there be any other chemical principles in operation, which express themselves in the presence or absence or mutual relations of specific minerals, such principles must be taken into consideration in the construction of the mineralogical groups, since they enable us to make those general propositions which are the soul of a classification.

If the difference between the saturated and the undersaturated rocks bears testimony to the operation of a general principle, namely, that every magma tends to saturate itself with silica, then this difference must find expression in our system. I believe in the reality of the principle just enunciated, basing my belief primarily on the evidence of the rocks themselves. I hold, therefore, that the operation of this principle should govern the mineralogical classification of rocks, and should be apparent in petrographical nomenclature. The degree of saturation is easily observed, except in the case of vitreous rocks, where all mineralogical criteria are equally inapplicable. It is the "sure mark of many other properties", such as the presence or absence of specific minerals, the capacity of the magma to assimilate foreign rocks, and the nature of the reactions thereby induced; furthermore, it throws light on the 'cooling-history' of the magma (which, as I read the facts, generally includes a progressive increase, but sometimes a local decrease, in the degree of saturation), and on the relations existing between the partial magmas or differentiates of an igneous complex. For all these reasons the criterion of saturation appears to me to be one which is eminently adapted to be used in the construction of a mineralogical classification of rocks.

I come now to the more specific criticisms advanced by Mr. Scott. My right to classify olivine as an unsaturated mineral is first questioned. The obvious way to defeat my contention would have been to adduce instances in which quartz and olivine are associated in igneous rocks. Mr. Scott mentions one or two cases of this association, and then plays into my hands by admitting that in one case the olivine, in another the quartz, is "probably xenocrystic". I am pleased indeed to have the additional evidence of Mr. Scott's

pitchstone-porphyries from Arran to add to the great weight of observations in favour of my view. We in this country are greatly handicapped in the matter of literature, and the paper in question had escaped my notice. In regard to the quartz-basalts of California and New Mexico, Lacroix[1] has opposed the views of Iddings and Diller, contending, not only on general grounds but also as the result of his own examination of the rocks in question, that the quartz of these basalts is really of foreign origin; he compares the rocks with lavas of Central France in which xenocrysts of quartz and felspar are just as evenly distributed, and yet are clearly of external origin.

Falling short of field evidence, Mr. Scott advances some theoretical considerations against my view. One of these is that the reaction

$$\text{olivine} + \text{silica} \longrightarrow \text{enstatite}$$

may be appreciably reversible under magmatic conditions. If so, where is the evidence of it? It cannot be mere chance which decrees that olivine and enstatite or hypersthene shall commonly occur together, that hypersthene and quartz shall be associated still more frequently, but that quartz and olivine shall never coexist except in circumstances which suggest that one is of extraneous origin. In some cases an olivine-bearing magma has been frozen in the very act of absorbing quartz and developing hypersthene or another pyroxene; numerous instances of this will be found in Lacroix' studies of the reactions between lavas and their inclusions.[2] Mr. Scott has himself explained the appearance of hypersthene in a rock at Garabal Hill by reaction between olivine and quartz.[2] Negative evidence as to the incompatibility of these two minerals is extraordinarily abundant, and he will find some of it at his hand in the intrusions of Kilsyth-Croy, which, according to Tyrrell,[3] contain hypersthene where quartz is present, and olivine only where quartz is absent. Even laboratory work points in the same direction. Daubrée[4] found that when he melted olivine in siliceous crucibles, the melt attacked the crucible with great energy and formed pyroxenes. He concluded from this that the rarity of peridotites in nature is due to the fact that the peridotitic magma tends to dissolve siliceous rocks and so to change its character.

Lastly, Mr. Scott quotes against my view the work of Anderson and Bowen[5]—which comes hot from the printing-press—on the binary system MgO–SiO_2. Here at least is evidence worthy of consideration. When a melt of the composition $MgSiO_3$ was cooled down from a very high temperature, *forsterite* was found to crystallize out at about 1,625°, and was followed later by a mixture of $MgSiO_3$ and SiO_2 in the forms of clino-enstatite and cristobalite (probably). But Anderson and Bowen go on to show that forsterite is only produced above 1,557°; when crystallization takes place at any temperature between 1,200° and 1,557°, *only clino-enstatite is formed.* The latter temperature is in fact the point at which clino-enstatite

[1] *Les Enclaves des Roches Volcaniques*, p. 43.
[2] GEOL. MAG., November, 1913.
[3] Ibid., July, 1909, p. 299.
[4] Cited by Lacroix, loc. cit., p. 498.
[5] Amer. Journ. Sci., xxxvii, and Zeit. Anorg. Chem., lxxxvii, 1914.

transforms into forsterite and glass. It follows from these results that forsterite and free silica can only coexist in a magma which commenced to freeze at some temperature in excess of 1,557°. There is not a shadow of evidence that any natural magma had such an enormously high freezing-point (meaning the point at which freezing commenced). Every one of the common rock minerals whose melting-point is known freezes below 1,550°, and the majority of them much below it. The freezing-point of a magma must therefore be much lower still, in accordance with Raoult's Law, apart from all consideration of the action of 'mineralizers'. Brun [1] and others have shown that the melting-points of fresh lavas lie between 950° and 1,200°; the Palisade diabase of New York [2] is readily fluid, in the crucible, at about 1,200°; Goldschmidt [3] has estimated the maximum temperature which prevailed in contact zones in the Christiania district at 1,000° to 1,200°. The fact is, that instead of disproving my contention, the work of Anderson and Bowen actually proves it by showing that (in a dry melt) forsterite and free silica do not form side by side below 1,557°. Olivine includes fayalite, however, as well as forsterite, and the occurrence of fayalite together with quartz or tridymite in the lithophysæ of acid lavas and the druses of granites has been described by Judd, Lacroix, Iddings, Quensel, and others. Iddings [4] offers the following explanation:—

"... the concurrence of fayalite and quartz in lithophysæ in highly siliceous rocks shows that silicon may be deterred from forming the higher silicate under certain conditions, which appear to be, either those that permit the water present in rock-magmas to enter into combination with the silica, forming a hydrogen silicate $H_4 Si O_4$, which ... subsequently breaks up into H_2O and $Si O_2$ which may appear as quartz; or such that water may act catalytically to promote the immediate separation of quartz before the separation of the olivine compound from the solution."

This is a possible explanation of the conjunction of fayalite and quartz; it would apply especially to the contents of vapour cavities and druses, where magmatic water would be concentrated towards the completion of the freezing of the magma. But a simpler explanation is available which involves no supposition whatever. It is just this, that the compound $Fe Si O_3$ is incapable of independent existence under any conditions realized in nature—it is not known as a mineral—hence the lower silicate, fayalite, is stable even in presence of quartz. I ought, on this account, to correct my former lists of saturated and unsaturated minerals by adding the rare fayalite to the former, retaining only the magnesian olivines and forsterite in the latter. The change is a slight one, since practically all common olivine is magnesian and therefore remains on the unsaturated list. Washington, in his recent description of the volcanic rocks of Pantelleria,[5] describes an 'olivine' existing in small amounts in the acid lavas, and shows by analysis that this is a nearly pure fayalite,

[1] *Recherches sur l'exhalaison volcanique*, ch. vi.
[2] R. B. Sosman & H. E. Merwin, Journ. Washington Acad. Sci., 1913.
[3] *Die Gesetze der Gesteinsmetamorphose*, Christiania, 1912.
[4] *Igneous Rocks*, vol. ii, 1913.
[5] *Journal of Geology*, 1914.

not a magnesian olivine. He adds that "the olivine found elsewhere in highly siliceous rocks, as granite and rhyolite, is always fayalite, not common olivine or the magnesian forsterite".

Having disposed of olivine, I pass to Mr. Scott's other criticisms. The possibility of the production of unstable phases, which undergo transformation subsequent to the consolidation of the rock, is urged as likely to render the saturation criterion inapplicable. The alteration of leucite to nepheline and orthoclase is advanced in illustration of this. But the recognitions of such transformations has never presented any special difficulty. Pseudo-leucite is easily recognized as such in most cases, and uralite, serpentine, iddingsite, liebenerite, bastite, pinite, leucoxene, kelyphite, sprenstein, 'chlorite,' saussurite, nearly always betray their parentage. The difficulties which are introduced by such changes affect all mineralogical classifications, and will equally affect the ideal classification of the future. But it is not shown how such a transformation can change a saturated rock into an unsaturated one, or vice versa; hence the argument has no relation to the question at issue.

With regard to the garnets, why does it seem impossible that spessartite and almandite can be stable in presence of excess of silicic acid, while pyrope and melanite are unstable? We have just seen that this very difference exists, within a wide range of temperature, between forsterite and fayalite; and a parallel case can be found in the different behaviour of calcium carbonate and the isomorphous carbonates of magnesium, iron, zinc, and lead towards an excess of carbonic acid. The garnets themselves differ greatly in stability towards mineral acids, some being easily decomposed while others are very resistant. It is probably not too much to say that the end members of most isomorphous series of compounds differ in stability. As regards the effect of pressure on the production of garnets, spessartite is known both in granites and in rhyolites; melanite both in syenites and in phonolites; pyrope both in deep-seated eclogites and peridotites, and in serpentines which may have been lavas. Here is no evidence that the production of garnet requires special pressure conditions. The "observed facts of distribution", in the case of the garnets, are not to be refuted by deduction from such inadequate premises. If I am mistaken in my opinion of the relation of the garnets to silica, then the proof of it exists in the field and should be sought there. At the same time I freely admit that it would be desirable to have experimental confirmation—or refutation—of the unsaturated character of pyrope and melanite.

In conclusion, I see no reason to modify my views regarding the saturation criterion in petrography. Its introduction into the basis of the 'natural' classification of rocks, in conjunction with mineralogical constitution (properly used) and texture, will do something towards giving that classification a meaning and a precision which hitherto have been conspicuous by their absence. And its use will in no way prejudice the reform—or it may be the abolition—of that classification as knowledge advances.

IV.—A new Cirripede from the Cenomanian Chalk Marl of Cambridge.

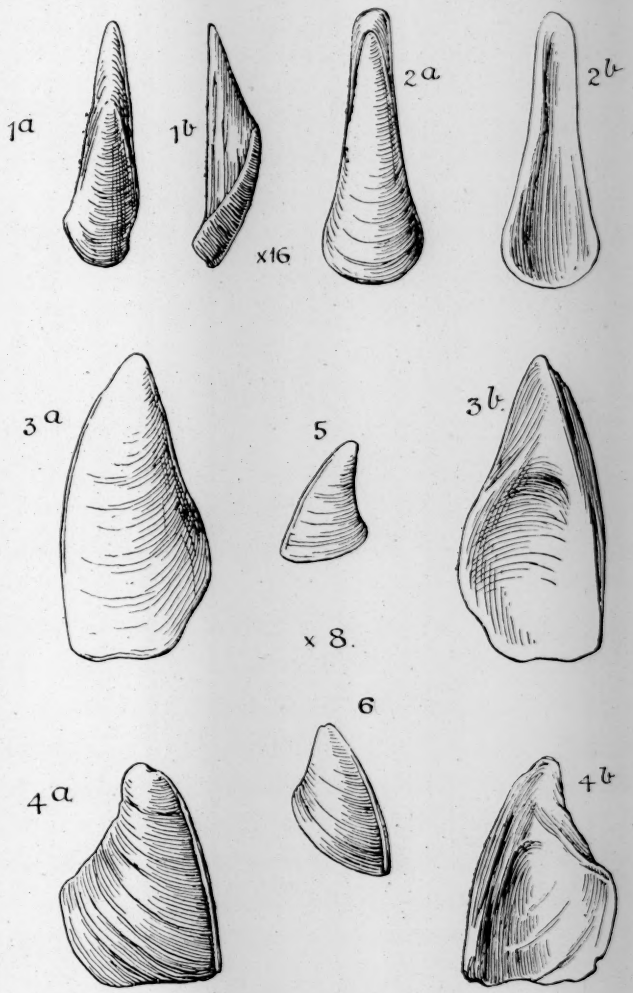
By Thomas H. Withers, F.G.S.

Of the Cirripedes obtained by the late Mr. F. Mockler from the Chalk Marl of Cambridge, two species, *Zeugmatolepas mockleri*, Withers, and *Calantica* (*Titanolepas*) *tuberculata*, Darwin, sp., have already been described and restorations given.[1] The remaining material consists entirely of disconnected valves, and among these are (1) a number of valves referable to *Pollicipes glaber*, F. A. Roemer; (2) a few valves of *P. rigidus*,[2] J. de C. Sowerby, together with some valves of a new species[3] which is probably related to *P. rigidus*; (3) an important series of valves belonging to several species of *Scalpellum* allied to *S. arcuatum*, Darwin, and *S. fossula*, Darwin; and (4) some valves that do not belong to any of the species already mentioned, and which it will be convenient to describe here.

Included in this last series are three minute carinæ and eleven scuta (seven left and four right). I have also a single carina from the Chalk Marl of Burham, Kent, and two scuta (left and right) from the Cambridge Greensand of Cambridge, and these are all precisely similar to the valves from the Chalk Marl of Cambridge. Except for the fact that these carinæ and scuta agree in having their outer surface smooth, and that they were found with a considerable number of valves of other species to which they do not belong, there is no evidence to show that they represent a single species. I am inclined to think that they do, but since they may belong to more than one species, it will be best if we regard the carina as typifying the species. It is noticeable that there are no terga among the valves, but if the terga happened to resemble closely those of *Zeugmatolepas mockleri*, which present considerable variation, there would be some difficulty in separating them. In point of fact, I have attempted to sort out a few valves from the large series of terga of *Z. mockleri*, but, while one could figure extreme valves as belonging to another species, one finds that they grade into other valves, and I have given up the attempt.

The carinæ, of which two from the Chalk Marl of Cambridge have been referred to by me (Proc. Zool. Soc. London, 1912, p. 531), represent the second species to be described from British Cretaceous rocks in which the umbo is in a sub-central position. Previously described Cretaceous species of *Scalpellum* with this advanced type of carina come from the Upper Senonian, so that the occurrence of a similar form so low down as the Cenomanian is especially interesting. I had, however, overlooked the fact that Darwin had already recorded, but not described, a carina from the Cretaceous of England with the umbo in a sub-central position. At the end of his description of the Tertiary *Scalpellum magnum* he says (1851, Pal. Soc. Mon. Foss. Lepadidæ, p. 21): "I may take this opportunity of stating, that

[1] Proc. Zool. Soc. London, December, 1913, pp. 937–48, pls. xciv, xcv.
[2] Ann. Mag. Nat. Hist., ser. viii, vol. xiv, p. 171, pl. viii, fig. 4, August, 1914.
[3] Tom. cit., p. 187, pl. viii, figs. 7–10.



SCALPELLUM PARVULUM, sp. nov.

FIG. 1. Carina (holotype). *a*, outer view; *b*, side view. Cenomanian, Chalk Marl: near Cambridge.
,, 2. Carina. *a*, outer view; *b*, inner view. Cenomanian, Chalk Marl: Burham, Kent.
,, 3. Scutum (right valve). *a*, outer view; *b*, inner view. Cenomanian, Chalk Mark: near Cambridge.
,, 4. Scutum (left valve). *a*, outer view; *b*, inner view.
,, 5. Scutum (small right valve). Outer view.
,, 6. Scutum (small left valve). Outer view.

Figs. 1–2 × 16 diam.; Figs. 3–6 × 8 diam.

in Mr. Harris's collection of organic remains from the chalk detritus, at Charing, in Kent, I have found the upper part of a carina of a very young and minute *Scalpellum*, which cannot be distinguished from this species [*S. magnum*]; but considering the state of the specimen, it would be extremely rash to believe in their identity. All the known cretaceous species have the umbo at the apex, so that the Charing specimen differs remarkably from its cretaceous congeners." Although search has been made among the Cirripede remains of the Harris Collection from the Charing detritus, now in the Geological Department of the British Museum, the specimen recorded by Darwin cannot be found. It is extremely likely, however, that it belonged to the species here described, since I am of the opinion that the Cirripede material seen by me from the Chalk detritus of Charing is of Cenomanian age.

Scalpellum parvulum, sp. nov.

Diagnosis.—Carina with the umbo situated from just below to about one-third the extent of the valve from the apex, outer surface smooth; apical portion acute and widening gradually downwards to near the basal margin, where the valve is somewhat expanded; tectum and parietes not separated by a ridge; inner margin of intraparietes straight.

Material.—Four minute carinæ, of which the longest measures 2·1 mm., and thirteen scuta, the largest of which has a length of 5·2 mm. and a breadth of 2·4 mm.

Holotype.—The carina (Text-figs. 1*a*, *b*).

Horizon and Locality.—Cenomanian, Chalk Marl: near Cambridge, and Burham, Kent. Cambridge Greensand: near Cambridge.

Description of Valves.—Carina angularly bent, with the umbo varying in position from just below to about one-third the extent of the valve from the apex; the valve is acute at the apex, and widens gradually downwards until near the basal margin, where the valve is rather abruptly expanded; tectum smooth, transversely rounded, not distinctly separated from the parietes; intraparietes wider than half the width of the basal portion of the valve, separated from the parietes by a distinct ridge, and by their upward growth form that part of the valve above the umbo; inner margin of intraparietes straight. Outer surface smooth; inner surface deeply concave, not narrowed under the umbo.

Scutum sub-triangular, outer surface smooth, with an extremely narrow raised rim extending along the occludent margin, and without the slightest trace of an apico-basal ridge; moderately convex transversely, apical portion acute and slightly curved towards the terga. Occludent margin slightly convex; basal margin, in some specimens making almost a right angle with the occludent margin, and in others is sharply upturned and blends into the lower part of the tergo-lateral margin; upper part of tergo-lateral margin slightly concave, and the tergo-lateral angle rounded. On the inner surface the occludent edge is flat and slightly overhangs the rather shallow pit for the adductor muscle; from the tergo-lateral margin, opposite the

adductor muscle pit, a slight ridge extends obliquely upwards and inwards to the occludent edge, and above this ridge an obtusely angular portion of the valve is depressed and marked with growth-lines, and evidently served for the reception of the scutal angle of the tergum.

Remarks and Comparison with other Species.—Although the four carinæ of *S. parvulum* are very small, the fact that they are all of about the same size seems to show that they are mature valves. A large amount of material has been carefully looked over, but these four carinæ only were found, so the species is probably rare.

The known Cretaceous species with the umbo of the carina situated sub-centrally number three only, namely, *S. beisseli*, Bosquet and Müller,[1] *S. darwinianum*, Bosquet,[2] and *S. hagenovianum*, Bosquet,[3] one of which *S. darwinianum*, has been described[4] from the Upper Senonian of Salisbury, Wilts. *S. parvulum* is quite distinct from *S. beisseli* and *S. darwinianum*, for in these two species the upward growth of the carina is due to the almost equal upward and downward growth of the valve from the umbo, the parietes and intraparietes are not defined, and the outer surface is ornamented with numerous ridges radiating from the umbo. *S. hagenovianum* agrees in the upper part of the valve being formed by the upward growth of the intraparietes beyond the umbo, but differs among other characters in the intraparietes being ornamented with ridges, and in the tectum being flatly arched transversely with a rounded ridge on either side. The carina of *S. parvulum* resembles more closely that of the Tertiary *S. magnum*, Darwin, but in the absence of the remaining valves of the capitulum it is impossible to say whether the two species are related. In *S. magnum* the inner margin of the carina is markedly concave, and on the inner side the valve is usually narrowed below the umbo, whereas in all the carinæ of *S. parvulum* the inner margin is straight and the valve is not narrowed below the umbo, but widens gradually downwards from the apex and is expanded near the base. Moreover, in *S. magnum* the tectum is separated from the parietes by a ridge, while in *S. parvulum* the tectum and parietes are not defined. Although the absence of a ridge between the tectum and parietes may seem a trivial point, this ridge is clearly seen in quite young valves of *S. magnum*.

As regards the scutum tentatively considered as belonging to *S. parvulum*, it has the umbo at the apex, and therefore differs from *S. magnum*, *S. beisseli*, and *S. darwinianum*, which all have the umbo situated sub-centrally ; in its other characters it differs markedly from these and other known species. The scutum of *S. hagenovianum* is not known.

[1] J. Bosquet, *Notice sur quelques Cirripèdes récemment découverts dans le Terrain Crétacé du Duché de Limbourg*, Haarlem, 1857, p. 7, pl. i, figs. 4–7.

[2] J. Bosquet, Monogr. Crust. Foss. du Terr. Crét. du Duché du Limbourg, 1854, p. 46, pl. iii, figs. 6–12.

[3] Tom. cit., p. 49, pl. iv. figs. 13–16.

[4] T. H. Withers, "Some Cirripedes from the Chalk of Salisbury, Wilts": GEOL. MAG., Dec. V, Vol. VIII, p. 23, Figs. 3–4.

V.—The Wexford Gravels and their bearing on Interglacial Geology.

By Grenville A. J. Cole, M.R.I.A., F.G.S., and T. Hallissy, M.R.I.A., Geological Survey of Ireland.

I. Introduction.

THE shell-bearing gravels of the county of Wexford have become so well known on account of their fossil contents that the boulder-clays associated with them have received scanty recognition. Very diverse statements have been made in regard to the position of the gravels in the succession of superficial deposits, and they have frequently been confused with the 'marl' which was extolled by early writers upon agriculture. Nearly all the references to the manurial value of such materials in Co. Wexford refer to this marl, that is, to a shelly and calcareous boulder-clay. The gravels, however, have been commonly styled 'manure gravels' by geologists, and R. J. Griffith,[1] as far back as 1836, distinctly states that the shells are sometimes so very numerous "that the gravel is raised for manure".

Numerous 'marl pits', now sometimes overgrown, remain on the farm lands of the county, and their use is well remembered by the people. Their original development is quaintly referred to in Boate's *Natural History of Ireland*[2]—

> "The same," i.e. marl, "also is still very usual in sundry parts of England, being of an incomparable goodness: the which caused the English, who, out of some of those places where Marl was used, were come to live in Ireland, to make diligent search for it, and that with good success at last; it having been found out by them within these few years, in several places; first in the King's-county, not far from the Shannon, where being of a grey colour, it is digged out of the bogs; and in the county of Wexford, where the use of it was grown very common before this rebellion, especially in the parts lying near the sea; where it stood them in very good stead, the land of itself being nothing fruitful. For although the ground (for the most part) is a good black earth, yet the same being but one foot deep, and having underneath a crust of stiff yellow clay of half a foot, is thereby greatly impaired in its own goodness. In this depth of a foot and a half next under the clay, lieth the Marl, the which reacheth so far downwards, that yet nowhere they are come to the bottom of it. It is of a blew colour, and very fat (which as in other ground, so in this, is chiefly percieved when it is wet) but brittle and dusty when it is dry."

R. Fraser, in his *Statistical Survey of the County of Wexford*,[3] refers only to the 'marle' as being laid upon the land, and his description makes it evident that this marl was a boulder-clay containing marine shells.

R. J. Griffith (Sir R. Griffith) came across the deposit when engaged in his remarkable geological survey of all Ireland.[4] He notes an "extensive marl deposit in Wexford, some of the shells of which appeared to correspond with those of the crag". A year later he amplified this observation in a presidential address to the Geological

[1] Journ. Geol. Soc. Dublin, vol. i, p. 151.
[2] Edition by Thomas Molineux, Dublin, 1755, p. 57.
[3] Dublin, 1807, pp. 53–5, 76–8, 81, 85.
[4] "On the Geological Map of Ireland": Rep. Brit. Assoc. Dublin, 1835, Transactions, p. 58.

Society of Dublin,[1] when he described, as widely spread in the county of Wexford, a stratum of rolled gravel, 9 to 12 feet thick, "beneath a stratum of calcareous clay marl, of a drab colour." He notes that the shells in the gravel are sometimes very numerous, that the bed is possibly of the age of the Crag of Norfolk, and that the shelly raised beaches of Ireland are distinctly of later date.

T. Oldham, who was in communication with Griffith and with Griffith's colleague, Sir Henry James, emphasized some of these points in 1844,[2] but he apparently added nothing on his own account. Henry James[3] recorded his personal observations in 1846, and defined the Wexford succession as consisting of rolled and waterworn pebbles at the base, then sand, gravel, and drift, the last being considered to be of the age of the northern drift. A large block of coal was found in clays at Rathaspick near Wexford, which Griffith thought was wood-coal from Antrim. E. Forbes named the fossils that were collected, including seventy molluscan species, fifty-five of which are living in British seas. *Fusus contrarius* (*Neptunea contraria*) is said to occur a hundred times more numerously than the right-handed form. E. Forbes visited the Wexford area personally, and published his conclusions and his lists of species in the same year.[4] He states (pp. 377–8) that the shells indicate the parallelism of Newer Pliocene and glacial strata.

Robert Harkness next examined the deposits in 1869.[5] While his conclusions seem to us fully justified, he overlooks several important features in the field. He states, for instance (p. 549), that a Lower Boulder-clay is probably absent in Wexford, and that the gravels have no boulder-clay above them in the sections near the town (p. 544), which is true for certain cases only. He makes the important observation (p. 543) that at Castle Ellis about 40 feet of reddish-brown boulder-clay, with beautifully striated blocks, principally from Cambrian and Silurian strata, overlie the sands and gravels. From this he compares the gravels with those of Howth, which lie between two boulder-clays, and (p. 547) with those of Aberdeenshire and Caithness.

Harkness, with great justice, attributes the flints found in the gravels to some source in adjacent land now worn away. He places this land, however, in the English rather than the Irish Channel. From the nature of the shells he states that the gravels represent a less rigorous climate in Middle Pleistocene times.

E. Hull,[6] fully acknowledging the work of Harkness, placed the Wexford gravels with those of Killiney and Three-rock Mountain

[1] Journ. Geol. Soc. Dublin, vol. i, p. 151, 1837. The address was given on February 10, 1836.

[2] "On the more Recent Geological Deposits in Ireland": Journ. Geol. Soc. Dublin, vol. iii, pp. 62, 66.

[3] "Note on the Tertiary Deposits of the Co. Wexford": ibid., pp. 195–6.

[4] "Distribution of the existing Fauna and Flora of the British Isles, and Geological Changes, etc." (Mem. Geol. Surv. Great Britain), vol. i, p. 336, 1846.

[5] "On the Middle Pleistocene Deposits": GEOL. MAG., 1869, p. 542.

[6] "Observations on the general relations of the Drift Deposits of Ireland to those of Great Britain": GEOL. MAG., 1871, p. 294. Also *Physical Geology of Ireland*, 1878, p. 84; ibid., ed. 1891, p. 112.

near Dublin in his 'interglacial series', a position which he has since consistently maintained. He emphasized the existence of an Upper and Lower Boulder-clay at Killiney, a matter that has since been questioned. The Irish gravels were naturally at that time held to have been deposited in the sea during a temporary depression of the land; but Hull holds strongly that their occurrence indicates a milder climate,[1] after which a partial return of a cold climate produced local glaciers and icebergs. As regards Wexford, he indicates the superposition of an Upper Boulder-clay on the 'manure gravels', while apparently remaining unaware of the existence of the glacial 'marl' below the gravels.

G. H. Kinahan,[2] whose opposition to Hull's views must often be regarded as a matter of principle, promptly recorded his opinion that the Irish gravels lay on no definite horizon. James Geikie,[3] on the other hand, accepted Hull's opinion as to their interglacial character.

Kinahan, in order to emphasize his belief that the glacial series in Ireland was continuous, referred the gravels to the melting of the ice, and the boulder-clay above them to the downwashing and re-arrangement of the earlier glacial accumulations and other material on hill slopes. The Upper Boulder-clay was for him merely 'glacialoid'[4]; and in 1884 (see reference later) he remarked that many of the sands and gravels are probably younger than the material now lying over them. In 1876[5] he again urged that the deposit above the shelly or 'manure' sand of Wexford was not directly originated by ice. About this time he was engaged on the geological survey of Co. Wexford, and he records the succession of deposits far more clearly than any of his predecessors.[6] He relies especially on the coast-sections near Kilmore in the south of the county, and points out the existence of a green sand at the base. Near St. Patrick's Bridge (p. 44) he gives the upward succession as 'marl', 'gravel', and a 'glacialoid drift'; but elsewhere he often records the interlocking of gravel with his glacialoid drift. The green sand, as we shall see later, is not glauconitic, but is a chloritic derivative from the underlying Palæozoic rocks. In a subsequent memoir published in 1882[7] he mentions a thick mass of 'glacialoid' drift as underlying 'manure sand' at Ballynaclash, half a mile south-west of the mouth of the Blackwater. We may say at once that we regard Kinahan's efforts to distinguish a 'glacialoid' drift from boulder-clay as entirely academic, and that

[1] "Observations on the general relations of the Drift Deposits of Ireland to those of Great Britain": GEOL. MAG., 1871, p. 299.

[2] "Middle Gravels (?), Ireland": GEOL. MAG., 1872, p. 267.

[3] "On Changes of Climate during the Glacial Epoch": GEOL. MAG., 1872, p. 105.

[4] "Glacialoid or re-arranged Glacial Drift": GEOL. MAG., 1874, p. 111. On p. 113 Kinahan states that his glacialoid drift occurs above and also interstratified with the Wexford gravels. On p. 172 he allows that local ice may have formed a true drift over gravels in limited areas of Ireland; but he opposes the idea of two separate glaciations.

[5] "Irish Drift. Sub-groups—Aqueous and Glacial Drifts": Journ. Roy. Geol. Soc. Ireland, vol. iv, p. 217.

[6] Geol. Surv. Ireland, Mem. to Sheets 169, 170, 180, 181, 1879, pp. 12–14, 28–51.

[7] Mem. to Sheets 158 and 159, p. 34.

no such discrimination is possible in the field in the areas selected by him as typical. Since he held, in common with most geologists at that time, that the gravels were deposited in a shallow sea, he regarded [1] the boulder-clay above them as an aqueous derivative from islands of the Lower Boulder-clay which stood out above the water.

Kinahan returned to the subject in 1884,[2] and certainly added to the discussion by his clear realization (p. 272) of the conditions that prevail where pure and stone-bearing masses of ice melt away side by side during the decay of a continental ice-sheet.

Since the Newer Pliocene character of the fauna of the Wexford gravels had been emphasized by Forbes (see *ante*), an important remark was made in 1886 by P. F. Kendall & R. G. Bell.[3] Following the stratigraphy established by Kinahan, these authors point out that the Wexford gravels are of Glacial age. In spite of this, A. Bell has since maintained that they are pre-Glacial,[4] and his statements as to the succession of the strata deserve especial mention.

A. Bell is clearly "the writer" referred to in the report on the "Manure Gravels of Wexford", by R. Etheridge, H. Woodward, and A. Bell.[5] It is to be regretted that the associated authors were not in a position to unite in observations in the field. In their first report it is stated that the Wexford gravels are "purely local and bear no marks of ice action, and it is very questionable if this part of Ireland has ever been subjected to glacial action as ordinarily understood". In the second report [6] the succession, in spite of Kinahan's work, is given as "(1) 'manure' gravel series; (2) marls and clays; (3) an illusory or fictitious drift". The marls and clays, which in reality form the base, are said in part to cover the gravels. From pp. 134 and 135 it is clear that the deposit styled an "illusory drift" is identical with that correctly determined by Harkness as boulder-clay abounding in striated blocks.

On p. 138 the section at Killiney in Co. Dublin is discussed, and here an older drift is recognized, with gravels resting on it. The upper portion of the Killiney cliff is unfortunately described as consisting of "smaller gravel".

The third report of the British Association Committee (1889) is merely an *interim* record of progress. The fourth report [7] emphasizes the large number of extinct mollusca in the Wexford gravels (p. 423), as compared with nine other localities of shell-bearing gravels.

In 1892 A. Bell summarized his conclusions.[8] He again (p. 662) makes the remarkable assertion that the series of Wexford sands "rests directly upon Palæozoic rocks and is remarkably free from

[1] Mem. to Sheets 169, etc., 1879, p. 12.

[2] "Note on the Classification of the Boulder-clays and their associated Gravels": Journ. Roy. Geol. Soc. Ireland, vol. vi, p. 270.

[3] "On the Pliocene Beds of St. Erth": Quart. Journ. Geol. Soc., vol. xlii, p. 208.

[4] Proc. Roy. Irish Acad., ser. III, vol. ii, 1892, p. 621.

[5] Rep. Brit. Assoc., 1887, p. 210.

[6] Rep. Brit. Assoc., 1888, p. 133.

[7] Rep. Brit. Assoc., 1890, p. 410.

[8] "Note on the Correlation of the Later and Post-Pliocene Tertiaries on either side of the Irish Sea": Proc. Roy. Irish Acad., ser. III, vol. ii, p. 620.

signs of glaciation". He gives a list of eleven Pliocene and sixteen boreal species out of the total of about one hundred molluscan species recorded, and urges (p. 633) that the facies of the fauna of the marls of Rosslare Bay and Wexford Harbour is entirely different. He states that these marls overlap the sands and are of much later date. Bell's stratigraphical observations must be read with some reserve. His phrase "illusory drift", however, may be taken as a development of Kinahan's ideas.

As the result of a visit to the district for the examination of the soils of Co. Wexford, the present writers were much struck with the confusion still surrounding the stratigraphy of the local drifts. T. Hallissy[1] published a general statement in 1912, and a more detailed account of the succession now follows.

II. The Characters and Succession of the Wexford Drifts.

T. Hallissy has already stated our view (*op. cit.*, p. 178) that the 'marl' of Wexford represents "the englacial moraine of the Irish Sea ice-sheet which invaded this portion of the Wexford area from the north-east". This 'marl' is a chocolate-brown boulder-clay, effervescing on the application of hydrochloric acid. The well-known shelly gravels undoubtedly overlie it, and the loam (Kinahan's 'glacialoid' type and Bell's "illusory drift") that often occurs above these contains numerous striated stones and is identical with Hull's Upper Boulder-clay.

The deposits are widely distributed in the country to the east of the Leinster Chain, but are best developed in the south-east of Wexford, where they attain a maximum thickness of about 60 feet on the coast near Greenore Point; then, thinning towards the west, they occupy a considerable area of the county below the 300 ft. contour-line. As the chocolate clay is a highly calcareous deposit, possessing on an average about 11 per cent of carbonate of lime, it was formerly extensively used as a manure (see *ante*). The shell-bearing gravels likewise are said to have been added to the land with the same object,[2] though there is little traditional evidence to show that this has been the case. At any rate, their use for manurial purposes could not have been very general, as no pits that could have supplied a large quantity of material remain in evidence. Both the chocolate clay and the sands and gravels contain numerous arctic and other shells, occurring mostly in a fragmentary condition, and from the latter deposit some distinctly Pliocene forms have been obtained. In addition, these deposits contain anthracite and bituminous coal, lignite, chalk-flint, jasper, diorite, felsite, red granite, etc. Many striated limestone and sandstone boulders have been found in the chocolate clay, and magnetic iron sand has been obtained from the sands and gravels. The occurrence of the sands and gravels is sporadic, being confined to certain localities situated at intervals over the area, while the 'marl' and non-calcareous loam form practically continuous sheets.

[1] "On the Superficial Deposits of the County of Wexford": Irish Naturalist, 1912, p. 175.

[2] R. Griffith, "Address": Journ. Geol. Soc. Dublin, vol. i, p. 151, 1837.

All three types of drift appear in a 35 ft. section at Crosstown, on the left bank of the Slaney, 1 mile N.N.W. of the town of Wexford. Here the chocolate clay rests on a limestone rock-floor and is overlain by about 6 feet of coarse shelly gravel followed by fine stratified sand, on the top of which repose about 6 feet of non-calcareous stony loam. Both the chocolate clay and the sands and gravels, but notably the latter, contain such considerable quantities of coal that borings or other trials for coal are said to have been made at this locality, though without success. As Griffith pointed out,[1] some of this coal is lignite, like that of Co. Antrim ; but a large amount of bituminous coal, and also of anthracite, occurs. Two and a half miles to the north-east of the Crosstown section, at Pollregan, near Castlebridge, is the sand-pit referred to by A. Bell in the second report to the British Association on the "Manure Gravels of Wexford".[2] The pit, yielding good building sand and containing numerous shell-fragments, is situated on a low gravel ridge rising from the general level of the 'marl', which bounds it on every side on the lower ground. Although the stratigraphical relations of the gravel to the other drifts cannot be seen in the actual pit-section, it is fairly safe to infer from its position that it overlies the marl. The superficial drift is absent, at least from the side of the ridge on which the gravel-pit occurs.

Another section studied by Bell is that of Little Clonard, about 2 miles W.S.W. of the town of Wexford. The gravel-pit at this locality yielded many well-preserved shells, and these, as well as the shells from the gravels of neighbouring districts, included some forms of late Pliocene age. This fact led A. Bell to refer the deposit to the same horizon as the St. Erth Beds, which he considers to be a south-eastern extension of the Wexford Gravels. Since he believed the 'marl' to be newer than the gravels, he described the latter as occurring beneath the 'marl' in this section. A careful examination of the section, however, shows that the gravel rests on the 'marl', and is overlain by the non-calcareous stony loam (Upper Boulder-clay), just as in the cliff-section at Crosstown.

The gravels are also well developed at The Deeps, near Killurin. In a new pit at this locality fine and coarse stratified sands are seen resting on the 'marl' as before, and capped by a couple of feet of soil representing the non-calcareous loam of other districts. Magnificent sections of these deposits are exposed for about 4 miles along the coast from Rosslare to Ballytrent, south of Greenore Point, and on the southern coast from Kilmore Quay to Tacumshin Lake. Perpendicular cliffs of drift up to 60 feet in height, which are being rapidly eroded by the sea, are seen in the neighbourhood of Greenore Point. The great bulk of the deposit consists of chocolate clay containing numerous beautifully glaciated boulders, fragmentary shells, coal, flint, jasper, chalk, etc., and at one point it is seen to rest on a glaciated rock-surface with striæ bearing N. 47° E. At other places along this coast the clay overlies a few feet of local

[1] See James, Journ. Geol. Soc. Dublin, vol. iii, p. 196, 1846.
[2] Rep. Brit. Assoc., 1888, p. 134.

rubble, which probably represents the 'head' on the pre-glacial rock-platform which has been noted in this locality.[1] The sands and gravels appear in these cliffs as a coarse gravelly bed near the surface, and in places the loam is represented by a few feet of soil at the top. Some lenses of fine sand were also noted interstratified with the 'marl', and the latter sometimes shows a very delicate lamination, like that referred to by Sollas & Praeger[2] as the 'tea-leaf' type.

The same succession of drifts that has been observed in the sections already described prevails also in the low cliffs along the southern coast from Kilmore eastwards. A section similar to that of Crosstown is exposed at Bastardstown, where the 'marl', the base of which is not seen, underlies some 15–20 feet of stratified shelly sands and gravels, and another section at Ballygrangans exhibits the same stratigraphical succession. In both these cases Kinahan[3] has described the *basal* drift as glacialoid. Both the 'marl' and gravels, like those described from other localities, contain, besides fragmental shells, coal, flint, chert, glaciated limestone boulders, etc., and they normally underlie about 5–7 feet of non-calcareous loamy boulder-clay. The 'marl' is seen to thin out gradually towards the west, and it disappears locally at Kilmore.

A very interesting section was noted in the cliffs at Nemestown, west of St. Patrick's Bridge, near Kilmore, in which the following succession occurs:—

6. Non-calcareous gravelly loam	5 feet.
5. Gravel	9 inches.
4. 'Marl'	5 feet.
3. Ferruginous stratified clay	5 inches.
2. Brownish stratified clay	6 inches.
1. Greenish sandy loam, the base of which is not seen	2 feet.

The greenish sandy loam, which we may call the 'Nemestown Loam', underlies the marl along this part of the coast; it is sharply differentiated from the superincumbent 'marl', and appears to have undergone denudation before the latter was deposited. Kinahan[4] supposed the Nemestown Loam to be glauconitic in character and similar to the Greensand associated with the English Chalk. A microscopic examination, however, shows that the green colour of the deposit is due, not to the presence of glauconite, but to that of chlorite, which is probably derived from the altered Palæozoic rock (gneiss and slate) on which it rests. The material contains angular fragments of the local rock, lying at all angles in it, and quartz pebbles, possibly derived from Old Red Sandstone, and may represent a pocket of the pre-glacial soil that remained undisturbed by the passage of the great glacier from which the 'marl' was deposited. In the eastern part of Nemestown Strand, the Nemestown Loam and the chocolate marl above it are alike overfolded, no doubt by the

[1] W. B. Wright & H. B. Muff (now Maufe), "The pre-Glacial Raised Beach of the South Coast of Ireland": Proc. Roy. Dublin Soc., vol. x, 1904, p. 300.

[2] *Irish Naturalist*, 1895, p. 321.

[3] Mem. to Sheets 169, etc., 1879, p. 47.

[4] Mem. to Sheets 169, etc., p. 43.

pressure of ice moving from the north-east. On weathering, the chocolate marl shows a distinct lamination.

In spite of occasional loamy bands in the gravels and of gravelly patches in the boulder-clays, we have no doubt that Hull's main contention [1] is correct, and that Wexford, like other parts of Eastern Ireland, records (1) an invasion of foreign ice from the north and north-east, (2) an epoch of recession, which allowed of the formation of shelly gravels as a residual concentrate from the englacial moraine (boulder-clay) which was left behind by the shrinking ice, and (3) a second boulder-clay, in which local rocks are conspicuous, and which represents a return of colder conditions and an extension of the Irish ice.

We agree with Kinahan and Wyley [2] that the flints found in the Wexford drifts were derived from a region of chalk which once stretched across the Irish Sea and the English Channel. Recent work [3] clearly shows how much Cretaceous material has been lost during the formation of the North Atlantic and its eastern inlets. The beach east of Kilmore contains numerous large and almost unrolled flints, which probably come from chalk that still remains in the floor of the adjacent sea. They are larger and fresher on their surfaces than those found in the chocolate clay. The coal that is so abundant in this clay near Wexford town is no doubt derived from the waste of Carboniferous strata, while the lignite, which is found also at Kill of the Grange in Co. Dublin,[4] may represent a widely spread Cainozoic stratum, and is of too frequent occurrence to be attributed to the beds of Co. Antrim.

The Pliocene shells, on which A. Bell has laid such stress, are no doubt also derivative. The Pliocene sea, of which the St. Erth Beds are a record, is held to have formed the plane surface of northern Cornwall,[5] which clearly corresponds with that of South-East Ireland. The finding of iron-stained shells in the drift of Co. Carlow has been cited [6] as fair evidence of the existence of Pliocene deposits in Ireland, which have been concealed by the boulder-clays, or which have been worked up later into them.

There can be little doubt that the shells of the Wexford gravels have all been derived by concentration from the chocolate boulder-clay that was deposited from the Irish Sea ice. The same is true of the stony materials that form the gravels. Any of these materials may in turn have found its way into the later boulder-clay which overlies both the gravels and the chocolate clay; but this later boulder-clay is far richer in subangular blocks of local origin.

[1] *Phys. Geol. Ireland*, 1878, p. 84.

[2] Mem. to Sheets 169, etc., 1879, p. 13.

[3] G. A. J. Cole & T. Crook, "Rock-specimens dredged from the Floor of the Atlantic" (Mem. Geol. Surv. Ireland), 1910. A. Jukes-Browne, *Building of the British Isles*, 1911, fig. 53.

[4] W. J. Sollas & R. Ll. Praeger, "Notes on Glacial Deposits in Ireland. II. Kill o' the Grange": Irish Naturalist, 1895, p. 321.

[5] H. Dewey, Proc. Geol. Assoc., vol. xxv, p. 173, 1914.

[6] G. A. J. Cole, "The Problem of the Liffey Valley": Proc. Roy. Irish Acad., vol. xxx, sect. B, p. 11, 1912.

We may now compare the Wexford Series with that in Co. Dublin, on which Harkness[1] and Hull[2] so largely based their threefold division of the Irish drifts.

III. Comparison of the Wexford Drifts with those near Dublin.

Mainly in consequence of the work of G. W. Lamplugh,[3] the shelly gravels near Dublin are now regarded as the product of local melting of glacier ice, and of the consequent washing away of the finer particles as the englacial matter was set free. The shells in them have been carried, with the Lower Boulder-clay, to their present sites by movements of the ice. Maxwell H. Close, while holding that the gravels represented a submergence, was wont to say that the molluscs had certainly not lived in the beds in which they now are found. They are, in fact, concentrated from a shelly boulder-clay, that is, from the englacial burden brought in by the Scottish ice from the Irish Sea.

The unwashed boulder-clay of this Scottish ice is typically seen in the brick-pits at Kill of the Grange, 1 mile south-west of Kingstown. This deposit and its shelly contents have been fully described by Sollas & Praeger,[4] who state (p. 327) that, though it rests on granite, only one pebble of granite was found among 129 stones collected. A northern origin is assigned to this deposit. J. R. Kilroe in the Survey memoir on the country around Dublin states[5] that the Kill of the Grange clay is older than the Killiney sands and gravels, and than the layers of boulder-clay interstratified with them.

The Kill boulder-clay, which is also well seen in pits nearer to Cabinteely, is greyish to chocolate brown, and strikingly recalls the lower 'marl' or boulder-clay laid down by the Irish Channel ice in Wexford. The fact that it similarly effervesces with acid has not, we believe, been previously noticed. Lignite occurs in it in fair abundance, doubtless from some source now covered by the sea.

Such very different statements have been made about the neighbouring section in the sea-cliff below Killiney station that we might well hesitate to express an opinion here. But we find a marked difference between the chocolate clay, containing few stones, which is revealed at the base towards the south end of the section, and the boulder-clay with large blocks of local granite that overlies the gravels.[6] An overthrust, probably due to the pressure of ice lying somewhere towards Bray, and slipping northward during the epoch of melting, has pushed up the chocolate clay over a portion of the stratified gravels; but the three deposits seem to us sufficiently distinctive, and to support the triple classification long ago advocated by Hull. It cannot be a matter of accident that the chocolate clay,

[1] "On the Middle Pleistocene Deposits": Geol. Mag., 1869, p. 542.
[2] Op. cit., Geol. Mag., 1871, p. 294.
[3] Mem. to Sheet 112, 2nd ed., 1903, p. 45.
[4] Op. cit., *Irish Naturalist*, 1895, p. 321.
[5] Mem. to Sheet 112, 2nd ed., 1903, p. 108.
[6] Hull's view that this is a true boulder-clay (letter in Geol. Mag., 1872, p. 335) has been supported by all recent writers.

which so closely resembles that of Wexford, effervesces when touched with acid, while the matrix of the Upper Boulder-loam gives no reaction.

Mr. W. D. Haigh, A.R.C.Sc.I., has made the following determinations for us in the laboratory of the Geological Survey of Ireland:—

PERCENTAGE OF CALCIUM CARBONATE IN CHOCOLATE CLAY.

Greenore Point, Co. Wexford	9·83
Rosslare, Co. Wexford	12·97
Killiney, Co. Dublin	11·15
,, ,,	10·56
Kill of the Grange, Co. Dublin	11·80
Rochestown Avenue, near Cabinteely, Co. Dublin	9·76

The continuous sections in the county of Wexford are more imposing than those of Dublin; but enough is still seen at Killiney to justify a comparison, and, we believe, an accurate correlation.

We thus find ourselves in disagreement with Kinahan, who denies the existence of an Upper Boulder-clay at Killiney[1]; in agreement with Lamplugh, who accepts an Upper and a Lower Boulder-clay with gravels between them; but in disagreement with Lamplugh and Kilroe,[2] when they minimize the importance of the lower clay and regard it as a mere interlamination in the gravel series. Nor can we agree with Kilroe that the red colour of this clay is due merely to 'progressive weathering'. The sections in the county of Wexford produce a very different impression.

It is noteworthy that the clay brought from the North Sea over the east of England by the great extension of ice from Scandinavia is characteristically of a reddish buff colour.[3] This may be the colour of submarine sediments that became incorporated in the ice-sheet, though O. B. Böggild[4] states that a brown tint is very rare in such deposits if they are of terrigenous origin. Böggild regards the brown colour of such sediments as due to an oxidizing action of the sea on deposits that would ordinarily be grey or blue or green. Fritz Heim,[5] in his examination of specimens from the Atlantic, concludes that red clays are not necessarily derived from the clays of other tints that underlie them, but represent a stage when the area happens to be far from land. He suggests that a difference of colour in the deposits at any one spot indicates a tectonic change. Hans Spethmann[6] states that in the Baltic, off south-eastern Sweden, a chocolate colour is associated with a high percentage (some 13 per cent) of calcium carbonate; but his tables do not bear this out for other areas.

[1] "Middle Gravels (?), Ireland": GEOL. MAG., 1872, p. 265.

[2] Mem. to Sheet 112, 1903, pp. 40, 104.

[3] P. G. H. Boswell, "On the occurrence of the North Sea Drift": Proc. Geol. Assoc., vol. xxv, p. 150, 1914.

[4] "Mémoire sur les sédiments sous-marins": Croisière océanographique de la Belgica dans la Mer du Grönland (Bruxelles, 1907), p. 6. Also Report on the Danish Oceanographical Expeditions 1908–10 to the Mediterranean, p. 259.

[5] "Bericht über die Grundproben": Zeitsch. Ges. Erdk. Berlin, 1912, No. 2.

[6] "Studien über die Bodenzusammensetzung der baltischen Depression": Wissen. Meeresuntersuchungen, Kiel, Bd. xii, p. 313, 1910.

IV. An Interglacial Epoch in Ireland.

It would not have been surprising if the outlying region of the British Isles, exposed to considerable precipitation, had revealed no evidence of an interglacial epoch. While considerable shrinkage was going on in the Scandinavian ice-mass, the central parts of Ireland may have remained covered by a stagnating glacier, which melted so slowly that it was still in existence when glacial conditions again set in. We cannot, however, overlook the evidence of extensive melting, of the flow of broad bodies of water, and of the washing and denudation of the boulder-clay deposited by the ice which descended from Scotland along the Irish Sea. The deposition of that boulder-clay implies the reduction of the great glacier by melting from its surfaces. The waters from the residual masses swept across the moraine matter, which till then had been englacial, and gave rise to the Wexford gravels and their associates along the eastern coast.

The later boulder-clay represents the spread of Irish glaciers during an epoch which failed to reproduce the conditions of the previous ice extension. The large blocks of Leinster granite, which are so well seen in the new cuttings for the Dublin and South-Eastern Railway near Shankill, and which are so frequently observed in other places on both sides of the Leinster Chain, are among the most distinctive features of the second morainic sheet.

Harkness[1] observes that the Wexford gravels represent an epoch of less rigorous climate in Middle Pleistocene times. While Hull calls the Dublin gravels interglacial, and Praeger & Sollas[2] observe that they mark "a great change of conditions", Lamplugh states that they were formed during a recession of the ice.[3] The difference between these authors is evidently one of degree. The same relative positions are taken by those who advocate and those who deny that glaciers are great agents of erosion. No one really overlooks their erosive action, and the question becomes one of how many metres may be removed from a valley-floor during an ice age of unknown duration. The evidence in Ireland for the disappearance of the Scottish ice, whether from Antrim and Londonderry or Dublin and Wexford, is clear enough. The question is, could the local ice at the same time have undergone a great extension, or was there an interval which may be fairly styled interglacial?[4] If cold is the main factor in the production of a glacial epoch, warmth must be the main factor that brings it to an end. Changes in the amount of precipitation cannot be involved in this case. If glacial cold prevailed during the formation of the Wexford and Dublin gravels, the water necessary for their production could not have existed in the liquid state.

English geologists are meeting with the same question in the survey of their eastern drifts. While G. W. Lamplugh consistently maintains

[1] "On the Middle Pleistocene Deposits": Geol. Mag., 1869, p. 549.

[2] "Notes on Glacial Deposits in Ireland. I. The Bray River": Irish Naturalist, 1894, p. 198.

[3] Mem. to Sheet 112, 1903, p. 45.

[4] Cf. G. A. J. Cole, "Glacial Features in Spitsbergen in relation to Irish Geology": Proc. Roy. Irish Acad., vol. xxix, sect. B, p. 207, 1911.

that the British evidence shows only local features due to melting,[1] F. W. Harmer[2] believes that "a considerable interval" may have separated the invasion of the Scandinavian ice from the epoch of local glaciation. P. G. H. Boswell[3] agrees with Lamplugh that the middle sands and gravels of Eastern England represent a vicissitude, but not a "mild Interglacial Period". We venture to think that these authors, had they lived in early Pleistocene times, would have welcomed an epoch of rain and fluvioglacial flooding, with the temperature above 0° C., like that of summer in Spitsbergen, after the aerial hoar-frost and dry ice-surfaces of an ice-age, and would have felt that the new conditions could no longer be described as glacial. The Wexford gravels have already played their part in controversy. This fresh examination of them may prove of service in bringing that controversy to a close.

VI.—The Zone of *Offaster pilula* in the South English Chalk.

By R. M. Brydone, B.A., F.G.S.

(*Continued from p. 457.*)

IV. General Conclusions.[4]

I CLAIM to have now shown that the zone of *O. pilula* as established in 1912 for Hants and the Salisbury area holds good in its broad features also for Sussex, the Isle of Wight, and Dorset, and that it is almost equally constant in some of its minor features, especially the way in which it ends in a bed 2 ft. 6 in. to 3 feet thick with a flint seam in the middle of it and enclosed by two marl seams. I am only prevented by a single section in Hants from setting this up as the universal rule in all sections I have seen. In *The Stratigraphy* I assigned pits Nos. 1065, 1066, and 1067, the last of which will be more readily recognized as Mottisfont Whiting Pit, to the zone of *A. quadratus*, because on examining them for the purposes of that work for the first time since 1892 I had failed to find evidence of more than a seam of *O. pilula* without any others of the associated fossils of the zone. At the time of that examination all the pits were in a most unfavourable condition. Since then I have been keeping regular watch on the Whiting Pit (No. 1067), and I soon found that the subzone of abundant *O. pilula* must be represented at its base, and then that the upper belt of *O. pilula* in that subzone must be exposed :[5] but it was only this spring that I was able to fix the absolute position of the

[1] "The Interglacial Problem in the British Islands"; paper printed at the Congrès géol. internat. at Toronto, 1913.

[2] Discussion on paper by P. G. H. Boswell, Quart. Journ. Geol. Soc., vol. lxix, p. 581, 1913.

[3] "On the occurrence of the North Sea Drift": Proc. Geol. Assoc., vol. xxv, p. 129, 1914.

[4] Part I appeared in the August Number, pp. 359–69; Part II, September, pp. 405–11; Part III, October, pp. 449–57.

[5] The specimen of *A. verus* recorded from this pit and assigned to the zone of *A. quadratus* in *The Stratigraphy of the Chalk of Hants*, p. 99, may therefore have come from the uppermost beds of the zone of *O. pilula*; but the odds are in favour of the zone of *A. quadratus*, which occupies three-fourths of the pit.

boundary between the zones of *O. pilula* and *A. quadratus* in the Whiting Pit, and at the same time, owing to developments in the other two pits, to identify the *cinctus* belt in the old face and the lower belt of *O. pilula* in the new workings (and probably also at the lowest point of the old face) of Pit No. 1066, and the lower belt of *O. pilula* at the base of Pit No. 1065. The bed, which at the Whiting Pit ends the zone of *O. pilula* and contains the typical Offasters of exceptional size and shape, is enclosed by marl seams, but differs from the corresponding bed in all my other exposures in being 4 feet thick, hard, full of sponge remains, and devoid of flints, and the whole upper part of the subzone is notably poor in fossils and flints as compared with other Hampshire sections. I suspect that these variations indicate that Mottisfont was within the radius of the exceptional influence which must have been at work in the neighbourhood of Salisbury, which is already known through Dr. Blackmore for such striking abnormalities as the absence of *A. granulatus* at all horizons, and a concentration of *Belemnitella lanceolata* a few feet above the zone of *O. pilula*. It is therefore to be anticipated that in the Salisbury area the zone of *O. pilula* will be recognizable by its broad features; but correspondence in minute details is not to be expected.

Unfortunately it is an open question whether the zone I have defined can continue to bear the name of "zone of *O. pilula*". That name was preoccupied by the late Mr. Jukes-Browne in a paper published in the Geological Magazine for July and August, 1912, entitled "The Recognition of two Stages in the Upper Chalk", for a conception which was only defined piecemeal in this paper and a subsequent one in the Geological Magazine for April, 1913, entitled "The Division of the Upper Chalk". It was to correspond in Hants with the subzones of *E. scutatus* var. *depressus* and *O. pilula* as proposed by Mr. Griffith and myself in *The Zones of the Chalk in Hants*. In Sussex it was to embrace at least all the chalk above the zone of *Marsupites* exposed in the cliffs. In Yorkshire it was to embrace at least all the chalk above the zone of *Marsupites* exposed in the cliffs. But for each county he used a different test. The one he applied in Hants was quite vague, as the subzones on which he relied had at that time no defined boundaries except the lower boundary of the subzone of *E. scutatus* var. *depressus*; but it has since become most definite through the determination of these boundaries by me in *The Stratigraphy of the Chalk of Hants*.

The test which he applied in Sussex is clearly the periodical recurrence of bands of *O. pilula*, coupled with the occurrence of *A. granulatus*. Whether the Chalk of Sussex which he assigns to his zone responds to his test depends on the accuracy of the statement that "*O. pilula* is common at intervals *throughout* the 170 feet exposed in the cliff between Seaford and Brighton, while *A. granulatus* occurs through at least the lower 150 feet" (the italics are mine). This statement, so far as it relates to *O. pilula*, is accurately paraphrased from Dr. Rowe,[1] but as to half the Chalk in question its truth is, at any rate, highly debatable. So far as the statement

[1] *Coast Sections*, i, p. 342.

relates to *A. granulatus* it is presumably based on the Belemnite mentioned by Dr. Rowe[1] as found 150 feet above the zone of *Marsupites*. But Dr. Rowe does not state that this Belemnite was identifiable as *A. granulatus*; on the contrary, he states that it was not identifiable, but was considered to resemble *A. quadratus* and to be likely to be that species. Clearly, therefore, Mr. Jukes-Browne's test, even if a sound one, does not justify his assigning 150 feet positively, with a further 20 feet, as stated by him (really about 50 feet), by inference to his zone of *O. pilula*. On the other hand, the two specimens of *A. granulatus* 120 feet above the zone of *Marsupites*, recorded by Dr. Rowe on the same page, compel the assignment to Mr. Jukes-Browne's zone of *O. pilula* a minimum thickness of 120 feet. This is already 15 feet more than can respond to my zone of *O. pilula*, and the discrepancy is liable to be increased at any moment by the finding of *A. granulatus* at higher levels. The truth is that the granulated Belemnites are too scarce in South England in the middle of the *old* zone of *A. quadratus* to be treated as normal constituents of the fauna, when the enormous area exposed at this horizon in the cliffs of Sussex and inland in Hants is considered. At the moment of writing there are only thirteen accurately zoned and reliably identified specimens known to me from Hants and Sussex. They are distributed as follows:—

	A. granulatus.	Intermediate forms.	*A. quadratus.*
Chalk of zone of *A. quadratus* whose position can be fixed by reference to the zone of *O. pilula.*	Two in Sussex, 15 feet above zone of *O. pilula.*	—	One in Sussex, 8 feet above zone of *O. pilula.*
Subzone of abundant *O. pilula.*	—	—	Four in Hants. One in Sussex.
Upper part of subzone of *E. scutatus* var. *depressus.*	—	Two in Sussex.	One in Hants.

Note.—Two of the Sussex Belemnites have been found since the Sussex section of the paper went to press.

To these it may be added on Dr. Blackmore's authority that at Salisbury *A. granulatus* is not yet known at any of these horizons, which have been extensively worked, but two specimens of *A. quadratus* have been found in the lower belt and three in the middle belt of the subzone of abundant *O. pilula*, while in the upper belt of this subzone *A. quadratus* becomes definitely an established member of the fauna. Now that the range of this upper belt of the subzone has been established at Mottisfont, where it undoubtedly contains a fair number of granulated Belemnites, there should very soon be further evidence available from there.

Obviously the material is at present hopelessly inadequate to support even in theory the establishment of a zonal boundary for

[1] *Coast Sections*, i, p. 343.

South England dependent on [the range of *A. granulatus*; and it is impossible that such a boundary should ever be practicable in the field.

For Yorkshire Mr. Jukes-Browne's test is the presence of *A. granulatus*. There is nothing to my knowledge which justifies an assumption of correspondence between my zone of *O. pilula* in South England and all Yorkshire Chalk (above the zone of *Marsupites*) which contains *A. granulatus*. There is not even yet any evidence that *A. granulatus* has in Yorkshire the definite and constant range which it should have if its range is to determine a zonal boundary, much less that, if it has such a range, that range corresponds with a zone. Assuming that it has in Yorkshire a definite upward range, it is equally possible to argue that the Yorkshire range of *A. granulatus* is larger than my zone of *O. pilula* because the South England range of *A. granulatus* is larger than my zone of *O. pilula*, and to argue that the Yorkshire range of *A. granulatus* is less than my zone of *O. pilula* because in South England an interruption of the range of *A. granulatus* and apparently a passage of *A. granulatus* into *A. quadratus* take place in the middle of my zone of *O. pilula*.

The net result is that Mr. Jukes-Browne's zone of *O. pilula* is not identical with mine; and if his stands mine must fall.

Study of the zone of *O. pilula* inevitably draws attention to the remarkable differences between districts in the matter of marl in the Upper Chalk. The Hampshire student would leave that county convinced that above the zone of *M. cor-testudinarium* marl is an anomaly except for the subzone of abundant *O. pilula* and the zone of *B. mucronata*. Even the subzone of abundant *O. pilula* seems to be free of marl in the *cinctus* belt in Hants.

He would be surprised on reaching the Sussex coast to find that while the zones of *M. cor-anguinum* (apart from the *Uintacrinus* band) and *A. quadratus* were still practically devoid of marl, marl seams set in at the base of the *Uintacrinus* band and occurred at frequent intervals throughout that band and the zones of *Marsupites* and *O. pilula*, and he would find the same state of things in Dorset, though with a marked reduction in the extreme west at Middle Bottom in the degree of marliness. (It is curious that Dr. Rowe should have described the zone of *O. pilula* at Cockpit Head, which is full of marl seams, as "free from marly veins and bands".) In the Isle of Wight he would at last find the zone of *A. quadratus* beginning to give way to marliness at Culver Cliff and substantially affected by it at Scratchells Bay, though even here the zone of *M. cor-anguinum* still retains its character for purity. The obvious explanation, which I have heard given, is that the marl was introduced by currents. This explanation is quite inadmissible. No muddy current breaking into a calm sea could possibly spread itself so uniformly over such great distances as to deposit these exceedingly thin layers for the miles and miles for which they can be traced with certainty, and the far greater distances for which some of them, such as the marl seam which closes the zone of *O. pilula*, can be inferred to run without a break. To distribute itself in this way the current would require a speed and volume which would have swept the sea bottom into chaos, and it must have been shut out whenever a marl seam gives place to chalk, and reintroduced whenever chalk is succeeded

by a marl seam. The only possible explanation I see is that in the path of the prevailing wind, but a great way off, there lay a region of great but intermittent volcanic activity, and that the marl is wind-borne volcanic dust. Under these conditions there might easily be produced the thin sharply defined marl beds deposited continuously and in practically unvarying thickness over large areas at irregular intervals, which we actually find. The large quantity of marl that may be present in seams even in most typical 'White Chalk' is a point which seems not to have been realized by those who argue that the residue after solution of even a considerable thickness of 'White Chalk' *could* not suffice to produce the 'Clay with Flints'.

NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science, Eighty-fourth Annual Meeting, held in Australia, August, 1914. List of Titles of Papers read in Section C (Geology), etc.

(At Melbourne.)

Professor E. W. Skeats.—The Geology of Victoria.

Dr. T. S. Hall.—Victorian Graptolites. (p. 468.)

Joint Meeting with Section E on the Physiography of Arid Lands, opened by Sir Thomas H. Holland. Speakers: Professor T. W. Edgeworth David, Professor W. M. Davis, Professor J. W. Gregory (p. 419), Dr. W. F. Hume (p. 421), Professor J. Walther (p. 424), and others.

Mr. Ellsworth Huntington.—The Causes of Aridity in Post-Geological Times and the Bearing of this on Present Conditions.

Prof. E. W. Skeats.—On the Tertiary Alkali Rocks of Victoria. (p. 470.)

Dr. H. S. Summers.—On the Origin and Relationship of the Victorian Kainozoic Alkali Rocks. (p. 472.)

Dr. H. T. Jensen.—The Origin of the Alkali Rocks.

Mr. H. T. Ferrar.—The Permo-Carboniferous Breccia, a Desert Formation. (p. 465.)

Mr. H. T. Ferrar.—The Occurrence of Loess Deposits in Egypt. (p. 421.)

Professor A. P. Coleman.—The Climatic Conditions of the Early Pre-Cambrian. (p. 466.)

Mr. F. Chapman.—On the Age and Sequence of the Tertiary Strata of South-Eastern Australia. (p. 514.)

Dr. T. S. Hall.—Discussion on the Age and Sequence of the Victorian Tertiaries. (p. 517.)

Dr. G. B. Pritchard.—Discussion on the Age and Sequence of the Victorian Tertiaries. (p. 519.)

Professor J. W. Gregory.—The Correlation of the Australian Marine Kainozoic Deposits: Evidence of the Echinoids, Bryozoa, and some Vertebrates. (p. 516.)

Mr. D. J. Mahony.—The Evolution of Victoria during the Kainozoic Period. (p. 469.)

Mr. H. Herman.—On the Tertiary Brown Coal-beds of Victoria. (p. 466.)

Reports of Research Committees.

(At Sydney.)

Presidential Address by *Sir T. H. Holland.* (See *ante*, pp. 411–18, 457–64.)

Joint Meeting with Sections D, E, and K on Past and Present Relations of Antarctica in their Biological, Geographical, and Geological Aspects.

Mr. Frank Debenham.—The Sedimentary Rocks of South Victoria Land. (p. 467.)

Dr. A. Smith Woodward.—The Old Red Sandstone Fishes of Australia.

Mr. W. S. Dun.—The Palæozoic Coral Faunas of Eastern Australia.

Professor T. W. Edgeworth David and *Mr. W. S. Dun.*—On the term Permo-Carboniferous and on the Correlation of that System. (p. 468.)

Mr. E. C. Andrews.—The Post-Jurassic Geography of Australia. Notes on the Hypothesis of Isostasy. (p. 520.)

Mr. S. Dunstan.—The Geological Relations of the Artesian Water-bearing Beds of Southern Queensland.

Mr. E. F. Pittman.—The Great Australian Artesian Basin and the source of its supply

Mr. W. N. Benson.—The Occurrence of Spilitic Lavas in New South Wales.

Mr. C. A. Sussmilch.—The Metallogenetic Provinces of Eastern Australia.

Mr. L. A. Cotton.—The Genesis of the Diamond in New South Wales.

Professor E. S. Moore.—Structural Features of the Coal-fields of Pennsylvania. (p. 523.)

Reports of Research Committees: Ramsey Island, Pembrokeshire. (p. 522.)

Section K (Botany). (At Sydney.)

Professor A. C. Seward.—(1) The Vegetation of Gondwanaland. (2) The Older Mesozoic Floras of the World.

II.—*Papers read in Section C (Geology), Meeting of British Association, Australia, August, 1914.*

(1) On the Age and Sequence of the Tertiary Strata of South-Eastern Australia. By Frederick Chapman, A.L.S., Palæontologist to the National Museum, Melbourne.[1]

Divisions of the Kainozoic.—It is convenient to divide the Australian Tertiary system into four or five main series, using the local terms suggested by Hall and Pritchard. In ascending order, these, according to the writer, are: (1) Balcombian, (2) Janjukian, (3) Kalimnan, (4) Werrikooian. Above these comes the Pleistocene Series, referred by many geologists elsewhere to a separate system, the Quaternary. These divisions, broadly speaking, correspond with: (1) Oligocene, (2) Miocene, (3) Lower Pliocene, (4) Upper Pliocene.

The present writer maintains that, giving due allowance to time discrepancies in regard to the factor of distribution of life-forms over wide areas, guide fossils are probably as important in dividing and

[1] See also under Reviews, p. 526.

allocating these beds to the well-known horizons of the northern hemisphere as are percentages of living forms in these fossil deposits. The percentage method can only be used with safety as an approximate guide to age, seeing the difficulty of obtaining an agreement amongst zoologists as to what constitutes a species.

The above series of European divisions correlated with the Australian corresponds almost exactly with McCoy's original determinations, augmented by observations on faunas and stratigraphic relationship of the beds made by the writer during twelve years' attention to this subject.

Sequence of the Beds.—With regard to the sequence, some Victorian authors hold the opinion that the Janjukian Series is older than the Balcombian ; but the confusion seems to have arisen from the occurrence of a large number of persistent species, especially of Mollusca, passing up from the argillaceous Balcombian into the Janjukian Clay Series. Where faunistic and stratigraphic relationships were both doubtful the term Barwonian was suggested, which included both Balcombian and Janjukian. If, however, we regard the scope of the Janjukian in its broad sense as embracing all phases of sedimentation, of one long time series, the term Barwonian is no longer needed, its members being included in the term Janjukian. The sequence of the beds 1, 2, and 3 as given here has lately been established by the author from evidence obtained in cliff-sections at Muddy Creek near Hamilton, and in the bores put down in the Mallee and at Sorrento.

Other authors since McCoy agreed as to the present sequence, but differed in regard to the age of the oldest beds, which they held to belong to the Eocene, making the succeeding beds correspondingly older.

Guide Fossils.—The various members of the Australian Kainozoic system have been referred by the writer to the horizons given above, chiefly through a study of the Cetacean types, the fish remains, the Mollusca, the Polyzoa, the Ostracoda, and the Foraminifera. In the oldest beds (Balcombian) a predominant fossil is *Amphistegina*, long mistaken for *Nummulites variolaria*, the latter genus in reality being absent. In the limestone phase of the succeeding Janjukian beds the Miocene type of toothed whale, *Parasqualodon*, occasionally occurs; in the marls the Miocene genus *Spirulirostra*; whilst the Burdigalian forms of *Lepidocyclina* are abundant in the polyzoal series of the Janjukian. In the Kalimnan Series, Cetacea, known elsewhere in the Pliocene Crag (Diestian and Astian) of Antwerp and England as *Scaldicetus* and the ziphioid whales, are characteristic fossils. The above interpretation of the Australian Tertiary sediments agrees also with the data acquired by Australian physiographists, and is that generally accepted for New Zealand and Patagonia.

Terrestrial Series.—The terrestrial Tertiary deposits, so far as they are known, are assigned to the various horizons as follows :—

Balcombian.—Leaf-beds of Mornington and the brown coal of the Altona Bay Coal-shaft.

Janjukian.—Leaf-beds of Sentinel Rock (Cape Otway), Haddingley near Bacchus Marsh, Pitfield Plains, Narracan, Dargo High Plains,

and the Older Deep Leads: in Victoria. Leaf-beds of Dalton, Gunning, and Vegetable Creek: in New South Wales. Leaf-beds of Lake Frome, etc.: in South Australia.

Kalimnan.—Newer Deep Leads, Haddon, Victoria. Also of Gulgong in New South Wales.

(2) The Correlation of the Australian Marine Kainozoic Deposits: Evidence of the Echinoids, Bryozoa, and some Vertebrates. By Professor J. W. Gregory, F.R.S.

CORRELATIONS of the Kainozoic deposits which extend along Southern Australia have been proposed in accordance with two main conclusions. According to the first, these deposits include marine representatives of all the Kainozoic systems from the Eocene to the Pleistocene. According to the alternative explanation, most of the deposits belong to the middle part of the Kainozoic, and include essentially one fauna. When I succeeded M'Coy in Melbourne in 1900 I had to consider this question, and carefully examined the evidence given by the two groups of animals in which I was most interested, the Echinoidea and the Bryozoa, and also compared their evidence with that of some fossil vertebrates. The second correlation seemed the better to agree with the evidence of these groups. The Echinoidea had been regarded as indicating the Eocene age of some of the deposits, for one characteristic fossil had been referred to the genus *Holaster*. This determination had, however, been revised and the fossil referred to a new genus, *Duncaniaster*, whose affinities are with much later echinoids than *Holaster*. The fossil echinoids could all be included in one fauna; some of the most characteristic species, such as *Clypeaster gippslandicus* and *Monostychia australis*, range from the Balcombian to the Kalimnan, and *Lovenia forbesi* has the same variations in the Janjukian and Kalimnan. Some of the rarer species are limited to one locality, but that is probably only due to their scarcity. The characteristic Echinoids indicate one fauna, which is essentially Miocene, though it may have overlapped with the Upper Oligocene and Lower Pliocene. The evidence of the Echinoids is decidedly in favour of the view that there has been one great marine transgression along the southern coast of Australia, which reached its maximum in the Miocene if it were not confined to that system.

The evidence of the Bryozoa is less definite, but when carefully examined it supports the same conclusions. Many of the genera lived in the Eocene and Cretaceous; but most weight should be given to the most specialized Cheilostomata found in these deposits. Some well-known living species, such as *Retepora beaniana*, *Smittia reticulata*, and *Porella skenei*, are found in the Victorian beds, and they indicate an Upper instead of a Lower Kainozoic age. The survival of some older Bryozoa is less significant than the first appearance of the highly developed Upper Kainozoic species. Macgillivray in his monograph (1895) said that the Victorian Bryozoan fauna included no Eocene members, and that the different

horizons represented were not very different in age. With those conclusions I fully concur.

The vertebrate evidence appears to me to support the same determination. The appearance of *Squalodon*, *Scaldicetus*, and *Ziphius*, and of such well-known species of sharks as *Carcharodon megalodon* and *Oxyrhina hastalis*, which range from the lowest to the highest of the main Victorian marine series, is in favour of those beds being not earlier than Miocene. It is true that both species have been recorded from the Eocene of the United States; but these American Atlantic deposits are not an altogether satisfactory basis for correlation; and these species make their first appearance in the standard Kainozoic succession of Europe in the Miocene, and they last on to the Pliocene.

The classification adopted recently by Mr. Chapman seems to me in essential agreement with the evidence of the Echinoids, Bryozoa, and Vertebrates, most of the marine Kainozoic beds of Southern Australia belonging to the Janjukian and being of Miocene age.

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(3) Discussion on the Age and Sequence of the Victorian Tertiaries. By T. S. Hall, M.A., D.Sc.

THE chief difficulty that meets one in attempting to decide the age of the marine Tertiaries of Southern Australia is their wealth in well-preserved fossils. From the oldest series, the Barwonian, which includes the closely allied Janjukian and Balcombian, about 1,800 species have been described. This includes over 800 Mollusca, some 500 Polyzoa, and about 40 Brachiopoda, 50 Echinoids, 80 Corals, and a large number of Foraminifera. The Kalimnan yields about 260 described species, mainly Mollusca, while the Werrikooian affords close upon 200 species of described Mollusca. It may safely be said that when the fauna of the Barwonian, at any rate, is fully described the total will be doubled, for, taking the Mollusca, the small forms, which are extremely abundant, have not been touched, and a large number of new species in almost all groups are known, but remain undiagnosed.

The basis of classification is in dispute. In spite of all objections I adhere to the Lyellian percentage method as yielding the best results. Another method has been adopted by Ortmann in dealing with the Patagonian Tertiaries. It consists in comparing each species with species of known age in the northern hemisphere, deciding which is the nearest 'ally' or 'representative', and referring the southern formations to those northern ones which yield the greatest number of 'relationships'. It passes by as of no importance all the southern forms. Harris suggests using phylogeny *pari passu* with the Lyellian method.

The objection urged against the Lyellian method is that the personal equation enters too largely into it, and we do not know what a species is. H. von Ihering has discussed Ortmann's method fully, and objects to it. To my mind the personal equation is as prominent in it as in the Lyellian, and it demands an amount of

knowledge of the Tertiary faunas of the world that no one can possibly have at first hand, and enormous collections, quantities of each species, that no museum is likely to contain. As regards phylogeny, we cannot use it till we know the sequence.

Confining ourselves to the Mollusca, we find Tate recognizing about a dozen recent species in the Barwonian. Later authors have more or less definitely recognized about half a dozen more. As we have over 800 named species in this series of beds, we may double the number of recent ones without seriously affecting the result.

Assuming that the Barwonian is Eocene, for some age has to be assumed, I have elsewhere discussed most of the genera that transgress.[1] Some pass up from Mesozoic times, others are extensions back from younger horizons in the north, or from recent seas. Besides this the absence of many modern genera must be insisted on. It is customary for those who hold that the Barwonian is younger than Eocene to label all the old genera 'survivals'. This hardly settles the question. Leaving the land fauna on one side, there are some undoubted survivals in the Indo-Pacific, but it may be asked, did nothing originate in the southern seas and slowly migrate northwards? The real place of origin and age of the transgressing genera cannot be settled off-hand by northern standards.

The Barwonian is divided into Balcombian and Janjukian, but their relationship has been vigorously discussed. By far the greater part of the fauna is common to the two. Passing by the discussions between Professor Ralph Tate and Mr. J. Dennant on the one side, and Dr. G. B. Pritchard and myself on the other, which ended, as such discussions frequently do, in a series of flat contradictions as to facts, we may consider Mr. F. Chapman's position.

Mr. Chapman asserts that the Batesford limestone is typical Janjukian, and appears to conclude that all the polyzoal limestones—and there are many—are also Janjukian. He argues on the same data that the Janjukian is the younger series. Tate, Dennant, Pritchard, and myself, however much we differed on other points, agreed that the age of the limestones must be decided by reference to the rich fauna of the clays. Mr. Chapman makes no reference to an intercalated clay bed in the Batesford limestone from which Dr. Pritchard and myself collected forty-five species, mainly mollusca. Of these only one is confined to the type Janjukian locality, while twelve have never been found there, but are confined to typical Balcombian beds. The rest are common to both series. The limestone, then, as we asserted, is Balcombian and not Janjukian. Moreover, we showed, by a careful examination of the area, that the limestone passed under clays which are typically Balcombian, and can be traced to Orphanage Hill, only a couple of miles away. M'Coy grouped the Orphanage Hill beds with those of Mornington, that is, with the type Balcombian section. Tate, Dennant, Pritchard, and myself agree with the grouping, and Mr. Chapman still labels the Orphanage Hill fossils Balcombian in the National Museum. If, as Mr. Chapman asserts, the Batesford limestone is Janjukian, then the Balcombian is

[1] Rep. Aust. Ass. Adv. Science, Hobart, 1902: Pres. Address, Sect. C.

the younger and not the older member, as he asserts. The stratigraphical facts are unimpeachable.

The Mount Gambier limestones must, as the contained Mollusca show, be associated with the Balcombian of Muddy Creek. The polyzoal limestone of Muddy Creek rests on quartz porphyry, and is the basal member of the series. It has been traced by Dr. Pritchard and myself passing under the more loosely compacted beds of the district, and is inseparable from them.

The polyzoal limestones of Jan Juc, Waurn Ponds, and a few other places are Janjukian, and the evidence rests on the Mollusca, but this has no bearing on Mr. Chapman's main contention.

The relative age of the Janjukian and Balcombian is a difficult question. M'Coy, Tate and Dennant, and Chapman consider the Janjukian the younger. Dr. Pritchard and myself consider the reverse to be the case.

As regards the other formations, it may be briefly said that the estimate of their age depends on that of the Barwonian. If this be Eocene, they are Miocene and Pliocene respectively; if not, they must be placed higher in the scale.

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(4) Discussion on the Age and Sequence of the Victorian Tertiaries. By G. B. Pritchard, D.Sc., Lecturer in Geology, Working Men's College, Melbourne.

TERTIARY geology in South-Eastern Australia has been fruitful of much difference of opinion, partly on account of lithological variations associated with palæontological variations which have not always received due weight, the difficulty of correlating disconnected outcrops, bores, and shafts, and the degree of antiquity and relative age of the various horizons represented. The various changes in this work have no doubt been a stimulation to some, but to many it has been, and still is, very confusing.

It happens that marine deposits are well developed, many showing a remarkable wealth of fossils, and these have attracted more attention than their terrestrial and volcanic associates. Amongst the marine fossils, Mollusca are usually very striking, and it is only natural to compare these with Australian living forms. In this way a succession can be determined for the fossil faunas as at present known, showing further and further removes from the living.

1. *Werrikooian.*—The type locality is at Limestone Creek, a small tributary of the Glenelg River, in the parish of Werrikoo, South-Western Victoria. These beds bear a molluscan fauna strictly comparable with living forms along the southern coast except for the occurrence of a few species at present unknown amongst the living fauna.

2. *Kalimnan.*—The type locality is near the township of Kalimna, Gippsland Lakes, Eastern Victoria. The fauna of these beds is also comparable in general facies with the recent, in the proportion of bivalves to univalves, and relative abundance of representatives of other groups. It includes extinct genera, as well as a very high proportion of extinct species.

3. *Balcombian.*—The type locality is at Balcombe's Bay, east shore of Port Philip. The fauna of these beds is richer and more varied than the existing Southern fauna; its general facies is more comparable with Northern Australian forms. In the present state of our knowledge it contains rather more than 2 per cent of extinct genera, and even allowing a wide margin for differences of opinion the living species would barely represent 2 per cent.

4. *Janjukian.*—Coastal sections on Bass Strait, parish of Jan Juc, south of Geelong. The fauna from these beds appears to be furthest removed from the living, based on a review of the genera which shows between 5 and 6 per cent extinct, whilst the species only show about 1 per cent living forms.

When the typical fossils are not obtainable it is not easy to state whether a rock series is Balcombian or Janjukian. To meet this difficulty the wider term Barwonian has been given, as both these horizons are well developed in the Barwon Basin.

Stratigraphical evidence also exists in confirmation of the above sequence in the Moorabool Valley, in the coastal sections from Port Campbell to Cats' Reef and elsewhere.

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(5) The Post-Jurassic Geography of Australia. Notes on the Hypothesis of Isostasy. By E. C. Andrews, Sydney, New South Wales.

THE doctrine of isostasy implies the general correspondence, in weight, of all vertical columns of unit size composing the Earth's crust to a depth known as the *depth of compensation.* This depth is taken at 122 kilometres below sea-level by Hayford.[1]

The excess of height of the unit columns, in continental areas, is considered as being compensated by the excess of crustal density in sub-oceanic areas. Isostatic compensation is supposed to follow rapidly upon loading and unloading. Examples of such loading are sedimentation and the formation of a continental ice-sheet, while examples of unloading are erosion and the disappearance of an ice-sheet. The adjustment is considered to be a gradual, rather than a spasmodic, process. Anomalies of gravity, however, are recorded from many localities, and Gilbert[2] suggests that the explanation of such is to be sought in *nucleal heterogeneity.*

Geography.—East and West Australia form two positive, or buoyant, elements, while the Inland Plains, in the main, represent a negative, or sunken, area. With these three elements should be considered New Zealand, Malaysia, the South Pacific, the Indian, and Southern Oceans.

During Cretaceous time a great plain of erosion appears to have been formed in the positive elements of Australia, while the extensive epicontinental sea of that period was filled with the waste derived from the neighbouring erosion. Subsequently, both the old plain of

[1] J. F. Hayford, "Figure of the Earth and Isostasy": U.S. Coast and Geodetic Survey, Washington, 1909.

[2] G. K. Gilbert, "Interpretation of Anomalies of Gravity": U.S. Geological Survey, Washington, 1913.

erosion and the northern portion of the area of sedimentation were elevated to a moderate height and a long period of equilibrium and erosion ensued. This sequence of elevation and of pauses of equilibrium with erosion was repeated until the close of the Kosciusko Period,[1] the pauses between the uplifts becoming less important, but the amount of vertical movement becoming correspondingly emphasized.

At various stages of the process basalts flooded Eastern Australia, especially in areas of older sedimentation. The appearance of the old basalt-covered stream-drifts is suggestive of a temporary subsidence for the plateau areas during the basaltic period.

Strong streams, such as the Shoalhaven and the Hawkesbury, maintained their general courses against the uplifts along their lower portions. Hence it is inferred that the uplifts were effected slowly; nevertheless, the periods of equilibrium separating the revivals of elevation were of much longer duration than the uplifts themselves.

The researches of Dutton, Hayford, Bowie, Gilbert, and others appear to have placed the doctrine of isostatic compensation upon a firm basis; nevertheless, the operation of the adjustments does not appear, as yet, to be understood, and it is probable that cognizance has not been taken of all the factors.

In the example cited, of the elevation of both the great Mesozoic peneplain and a great portion of the loaded offshore area, it seems difficult, under the doctrine of continuous compensation, by erosion and sedimentation, to explain, in the first place, how the positive element could remain, for ages, in the one general position of equilibrium, while the offshore area was being loaded; and, in the second place, how the elevatory movement could have received its initial impetus, especially as the effect appears greater than the cause if it be assumed that the Cretaceous sedimentation gave rise to the Tertiary uplifts. On the other hand, the foundering of sub-oceanic areas in the neighbourhood might be adduced as an explanation, but the evidence is not at all conclusive on this point.

The history of the revivals of elevation during Tertiary time over Eastern Australia indicates crustal adjustment by jumps, and in this case also the increasing amount of vertical movement suggests that the elevations of the plateaus more than compensate for the erosion sustained in these regions during recent geological time.

The extrusion of basalts is in harmony with the doctrine, but the action appears to have been catastrophic rather than gradual in nature.

The sequence of geographical forms cited suggests that sedimentation influenced the formation of plateaus only in a minor degree, but, on the other hand, that stresses accumulated gradually within the zone of compensation, until a belt of weakness, or mobility, was established by means of which the ill-adjusted portions were connected. Upon the arrival of such a stage adjustment ensued with relative rapidity with the production of epeirogenic uplifts and depressions. This neither denies the ability of a load, such as a mass of sediments, or an ice-cap, to depress the underlying region, nor does it seek to exclude

[1] Closing Tertiary.

the tendency for an unloaded area to rise; it merely assigns to such agents a subordinate part in the shaping of the greater features of the Earth's crust.

It is probable also that an analysis of a series of gravity measurements which may be taken hereafter in Australasia would reveal the existence therein of gravity anomalies, and it is probable also that the disposition of these would be other than those which might have been inferred from a mere inspection of the topography.

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(6) Geology of Ramsey Island, Pembrokeshire. Final Report of the Committee, consisting of Dr. A. Strahan (Chairman), Dr. Herbert H. Thomas (Secretary), Mr. E. E. L. Dixon, Dr. J. W. Evans, Mr. J. F. N. Green, and Professor O. T. Jones.

THE Committee have to report that the grant made to them in 1913 to aid Mr. J. Pringle in continuing his researches in the west of Pembrokeshire has been spent. They have also to report that the detailed mapping of the island has been completed. The examination of the rocks and fossils which have been collected will be proceeded with.

For the purpose of description the island can be divided conveniently into two areas—a northern area composed of Lingula Flags, Arenig Mudstones and Shales, Lower Llanvirn, and the intrusive mass of Carn Ysgubor; and a southern area of Lower Llanvirn Shales with interbedded tuffs and rhyolites, and a thick mass of intrusive quartz-porphyry. To the latter area belongs the mass of rhyolitic and brecciated tuffs of Carn Llundain.

Northern Area.

Lingula Flags.—The Lingula Flags consist of bluish-grey, flaggy, micaceous shales with ribs of hard grey close-grained sandstone, some of which reach a thickness of 2 feet. They occupy the headland of Trwyn Drain-du, and they extend eastwards to Bay Ogof Hên, while on the eastern side of the island they form the cliffs from the north-east corner to Road Uchaf. The Flags also occur in the headland to the south of Abermawr. They are highly fossiliferous, and yield *Lingulella davisi* in great abundance.

Arenig.—All the zones of the Arenig are present. The lowest beds are bluish-grey sandy mudstones and shales with *Ogygia selwyni*, *Orthis proava*, and *O. menapiæ*. They are confined to the north-east corner of the island, and are faulted against the Lingula Flags. The mudstones are followed by bluish-black shales belonging to the Extensus zone, and are well displayed in the cliffs at Road Uchaf and Road Isaf. Similar shales belonging to the Hirundo zone are present in Abermawr.

Lower Llanvirn.—The base of the Lower Llanvirn is seen only in the cliffs in Abermawr, where the shales of the Hirundo zone are succeeded by a thick series of hard dark and light-coloured tuffs of fine texture, which yield *Didymograptus bifidus* in their highest beds. The tuffs are followed by fossiliferous blue-black shales, but their full thickness is not seen in the northern area.

Intrusive Rocks.—Carn Ysgubor is formed of an intrusive mass of quartz-albite-diabase, which has invaded the sediments of Lower Llanvirn, Arenig, and Lingula Flags. A small intrusion occurs south of Abermawr, where Lingula Flags are in contact with a quartz-keratophyre.

Southern Area.

This area was described in the first report, in which it was shown to be composed of *D. bifidus* shales which had been invaded by a thick mass of quartz-porphyry. The shales, well displayed in the cliffs of Porth Llanog and Foel Fawr, are highly fossiliferous, and a large collection of graptolites has been made from them. They contain layers of coarse agglomeratic tuff, and at Foel Fawr pass upwards into thick beds of tuff which are conformably overlain by grey rhyolites. The tuffs and conglomerate on Carn Llundain belong to the same period of eruption.

The two points of interest, therefore, which were made the object of mapping the island have been successfully solved. It has been found that the so-called Tremadoc Beds are Arenig sediments, and that they do not pass downwards into the Lingula Flags, but are brought against them by a fault; also that the rocks hitherto regarded as pre-Cambrian belong to a period of igneous activity that occurred in Lower Llanvirn, or even later, times.

It is hoped that the full description of the district will be completed this year, and it is the present intention of Mr. J. Pringle to communicate the results of his investigations to the Geological Society of London.

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(7) Structural Features of the Coal-fields of Pennsylvania and their Influence on the Origin of Hard Coal. By Professor E. S. Moore, M.A., Ph.D.

THERE are two main coal-fields in Pennsylvania, the Bituminous and the Anthracite. The latter field comprises an area of approximately 480 square miles situated in the highly folded portion of the Appalachian Province, while the former field covers a much larger area with but gently folded strata. Between these two fields are limited areas underlain by semi-anthracite coal in strata which have suffered a medium amount of diastrophism.

So close is the relationship between intense diastrophism and the development of anthracite coal, that the influence of pressure—combined with conditions favourable for the escape of the volatile constituents from the vegetable matter—seems to be self-evident, although other theories, such as the action of bacteria, etc., have been advanced to account for the origin of anthracite. The structure of some of the anthracite basins is extremely complex, and the coal can often be mined only by special methods, especially where the Mammoth seam reaches 60 feet in thickness.

In the Bituminous field, 'rolls' and 'horsebacks' are common, and investigation has shown that these, usually, nearly parallel the larger mountain structures.

REVIEWS.

I.—The Quaternary Ice Age. By W. B. Wright, of the Geological Survey of Ireland. pp. xxiv + 464, with 23 plates and 155 text-illustrations. London: Macmillan, 1914. Price 17*s*.

THE literature of glacial geology, both European and American, has of late years attained enormous proportions, and much of it is very inaccessible. The author has set himself the task of giving a summary of the latest conclusions in this interesting field, and it must be said that in this he has admirably succeeded. The book is evidently the result of a vast amount of reading, much of which must have been of monumental dullness, and the author's intimate acquaintance in the field with the Quaternary geology of the British Isles adds very greatly to its value and interest.

The whole forms an admirable summary of modernist views of glaciation and of the general geology of the Quaternary period in Britain, Scandinavia, the Alps, and North America, and the latest results of prehistoric archæology are freely utilized. It is becoming abundantly clear that in the study of human remains lies the best chance of solving the problem of the correlation of the British drifts with those of other areas, especially with regard to the occurrence of interglacial periods in this country.

To the majority of readers the most interesting portion of the book will be that dealing with the glaciation of Great Britain and especially of eastern England, as to which there is still much controversy. The author has here contented himself with an exposition of the land-ice theory in its most complete form. It should, however, have been made clear that the land-ice theory is not proven. The mechanical difficulties involved are very great. Even on the most favourable assumptions the possible angle of slope of the ice from the Scandinavian centre of glaciation to the Yorkshire coast is under 1°, and it is difficult to see how such an angle of inclination could produce sufficient driving force to bring about the tremendous effects postulated by the Yorkshire school of glacialists. Many of these difficulties have been effectively stated by Professor Bonney in his presidential address to the British Association at Sheffield. On this subject it is at any rate necessary to preserve an open mind, since with our present knowledge the problem seems to be insoluble. At any rate it is scarcely sufficient to dismiss the "Great Submergence" in four lines as a "geological fiction", as is done by the author.

Special attention is paid to the connexion between raised beaches and glaciation, and here comes the most original part of the book. According to the theory suggested the variations in the relative levels of land and sea are due to a combination of two causes: firstly, the actual lowering of the sea-level owing to accumulation of water on land in the form of snow and ice, and secondly, a slow isostatic rise of the land after removal of the heavy ice-cap which had previously led to depression of the region. This theory is worked out in a very convincing way with reference to the raised beaches of Scotland and the known variations of the Baltic which have been so ably studied by the Scandinavian geologists. It is argued that the pre-glacial

sea-level was much the same as at present. By this is presumably meant the immediately pre-glacial level, since the Pliocene plateau of southern Britain certainly indicates a much lower position of the land at that time. More attention might perhaps have been paid to the relation of the raised beaches of the south of England and of South Wales to the 'head' and other somewhat mysterious deposits that have been claimed as of glacial origin, since these seem likely to throw light both on interglacial periods and on the arrival of man in this country.

The general get-up of the book and the illustrations are excellent; it is perhaps permissible, however, to register a gentle protest against its inordinate weight.

R. H. R.

II.—Cambridge Manuals.

Coal Mining. By T. C. Cantrill, B.Sc., F.G.S. pp. 159. Cambridge University Press, 1914. 1*s.* net in cloth, 2*s.* 6*d.* net in leather.

THIS little volume forms an interesting addition to a well-known series. The author's aim has been to give a general sketch of the history and principles of coal-mining, and he has been quite successful.

In the introduction it is pointed out how intimately our whole civilization is bound up with this industry, and the history of the use of coal is traced from the earliest record, about 300 B.C., to the present day. Incidentally we are given an account of the evolution of the steam-engine in connexion with pumping and haulage.

We are next introduced to the various kinds of coal and their several uses, the geological conditions of its occurrence, and the use of fossils in distinguishing one part of the Coal-measure Series from another.

The value of a geological survey and the methods of prospecting and boring are discussed, also the difficulties which are encountered in the process of winning the coal, such as the accumulation of water or gas and the presence of faults and washouts. A good idea is given of the principal methods of working, ventilating, draining, and lighting the mine and of underground haulage.

Finally legal and administrative matters are dealt with. The book, although a mere sketch of the subject, has the outlines well arranged and is written in an interesting style, which holds the attention of the reader throughout.

III.—Canada Department of Mines. Geological Survey: Museum Bulletin No. 2. 8vo; pp. iv + 140 (of which 4 are printed as plates), 4 folding tables. Ottawa, July 30, 1914.

THE first number of this publication was entitled "Victoria Memorial Museum Bulletin No. 1", and was reviewed in the Geological Magazine for February, 1914 (p. 88). We then said that if it were "intended for the prompt publication of short papers

it might prove very useful". It may be that this is the intention, but we would deprecate any illusory appearance of promptitude such as is conveyed by the dates June 5, 17, 19, 22, July 3, 6, and 11, placed at the head of the respective articles, as though they had been published on those dates. We have no reason to suppose that such was the case, and indeed the fact that no copies were received over here before the second week in October leads us to regard even the alleged date of the whole number with some suspicion.

Mr. S. J. Schofield discusses the origin of the micro-pegmatite in the sills that traverse the Precambrian Purcell Series of British Columbia, and concludes that the rock was derived from the upper more acid stratum of a magma in an intercrustal reservoir, while the lower more basic strata gave rise to gabbro sills. Mr. Schofield also writes on the Precambrian (Beltian) rocks of South-Eastern British Columbia, and gives a new correlation table.

Dr. E. M. Kindle describes columnar structure in a bed of Silurian limestone in Eastern Quebec, and regards it as due to sun-cracks during deposition.

Mr. J. W. Goldthwait discusses and rejects various supposed evidences of subsidence of the coast of New Brunswick within modern time.

Mr. L. D. Burling contributes a paper on "Early Cambrian Stratigraphy in the North American Cordillera, with discussion of Albertella and related faunas", which he believes to occupy strata transitional between the Lower Cambrian sandstone and the Middle Cambrian limestone, and to be more related to Middle than to Lower Cambrian.

Miss Alice E. Wilson has studied the plications of the brachiopod shell *Parastrophia hemiplicata*, which show great variation. It appears that the plications came in gradually, following the natural process of individual growth, with gradual acceleration of development as geological time progressed. Palæontologists always seem to find that the transmutation of species has taken place in this way. Modern geneticists try to force another interpretation on the facts, but the process requires marvellous ingenuity.

F. A. B.

IV.—The Australian Tertiaries.[1]

ONE of the most interesting problems discussed at the British Association's meeting in Australia was the age of the Australian Tertiaries. Mr. Frederick Chapman, who brought to bear upon the question his wide palæontological knowledge, prepared and issued in July last as No. 5 of the Memoirs of the National Museum of Melbourne a paper "On the Succession and Homotaxial Relationship of the Australian Cainozoic System". After discussing the time equivalents, the relative value of the percentage method, comparison of typical faunas, widely distributed fossil types and their significance, he proceeds to dissect the evidence of the Foraminifera. Having shown that the so-called Nummulines are true Amphistegines, he

[1] See Notices, *ante*, p. 514.

writes a conclusive chapter on the complex-structured Foraminifera in the Australian Tertiary System, and fairly shows that the oldest Tertiary beds of the Australian Series can be no older than Oligocene, and that the Eocene formations are not represented in the continent as at present known. So far as the author can judge he correlates the Australian beds with the European equivalents as follows:—

Kalimnan = Pliocene (Lower).
Janjukian = Miocene: Aquitanian to Tortonian.
Balcombian = Oligocene: Priabonian to Rupelian.

Mr. R. B. Newton, who was present at the meeting, allows us to say that in his opinion Mr. Chapman's conclusions are substantially correct, the evidence of the Foraminifera being of especial value and importance in Tertiary times, while the Molluscan evidence strongly supports the Foraminiferal.

The stratigraphical notes bearing on the sequence of the strata are put together in a masterly fashion, will be of great value to workers both in and out of Australia, and will, we believe, add considerably to Mr. Chapman's reputation.

V.—Our Eastern Coal-field.

DR. NEWELL ARBER'S long-awaited paper on the Geology of the Kent Coal-field has now appeared in the Transactions of the Institute of Mining Engineers, xlvii (5), 1914, pp. 677–724. After a brief historical sketch the author gives the evidence which he has utilized consisting of an account of the various borings. He then discusses the form of the basin and its boundaries, the dip and strike of the beds and the faulting, with the contours of the Palæozoic floor. The age of the Carboniferous rocks met with, their lithology, types of coals, and flora and fauna occupy another section, and the paper ends with conclusions, summary, and bibliography. From the summary we learn that the field has an acreage of 128,000, of which a large portion lies under the sea. The general strike is 30° S. of E. and N. of W. and the dip (in the only two places where available) is 2 to 3. The area is a syncline occupying an anticline with folds of an Armorican trend. The northern boundary seems for the most part south of the northern coast-line of Kent. Upper and Lower Carboniferous beds are present, the latter exceeding 450 feet in thickness with surface denuded before the deposition of the Upper Series. The Coal-measures themselves consist of the Transition (1,700–2,000 feet) and the Middle (2,000 feet), the Lower with the Millstone Grit being unrepresented. They are grey; no red beds, Espley rocks, nor *Spirorbis* limestones occur. Igneous rocks have not been proved, and ironstones and limestones are either absent or very rare. The coals are well distributed, often of considerable thickness and value, but have a tendency to split. Altogether a highly valuable contribution to the geology of the South-East of England.

CORRESPONDENCE.

ORIGIN OF THE IGNEOUS ROCKS.

SIR,—I was much interested to read in your last issue the excellent review of Professor's Daly's latest work appearing above the initials "R. H. R." May I draw your reviewer's attention to the fact that such points as the quantitative composition of the igneous rocks and the effects of assimilation upon them have been dealt with at some length in England before now, as your own pages can testify. In this Magazine as long ago as June, 1904, I entered a protest against the calculations made on a purely arm-chair basis by F. W. Clarke and A. Harker with regard to the former problem, and Mr. Clarke has, to some extent, modified his calculations as a result of this and a succeeding paper on the same subject. With regard to assimilation, a process intimately connected with the question of composition, Professor Grenville Cole has been crying in the wilderness for many years past, and the late Dr. Johnston-Lavis has done good work in the same direction, while I attacked the problem on a much wider basis in a lengthy paper read before the British Association in 1905. This has been followed up by a general work on petrology, of which an expanded form was published by Messrs. Chapman & Hall last year. In substance it is a systematic exposition of the subject based on assimilation as opposed to the purely hypothetical 'differentiation' basis which has become so popular of late years. It may, perhaps, be added that Professor Daly has placed a great stumbling-block before many geologists by his advocacy of a prevailing basic magma, below the granitic one, as a primary feature of his work.

49 LONDON WALL, E.C., *Oct. 6, 1914.* F. P. MENNELL.

THE OLD OR GREY GRANITE OF THE TRANSVAAL AND ORANGE RIVER COLONY.

SIR,—On May 13 of this year a paper was read in the Geological Society of London by F. W. Penny, B.Sc., F.G.S., "On the Relationship of the Vredefort Granite to the Witwatersrand System" (see GEOL. MAG., July, 1914, pp. 332–3), wherein the writer suggests "that the Vredefort Granite, instead of being 'Archæan', is of a post-Pretoria–pre-Karroo age, if not contemporaneous with, at least connected with, the same epoch of igneous activity as the 'Red Granite' of the Northern Transvaal".

Thus nearly six years after the publication of my paper on "The Age of the 'Old or Grey Granite' of the Transvaal and Orange River Colony" in the GEOL. MAG., Dec. V, Vol. V, No. 534, pp. 552–9, another serious investigator arrives at the identical conclusion, evidently quite independently, as Mr. Penny, although quoting various authors, seems to have been quite unaware of the existence of my paper above mentioned.

I still hold the firm conviction that the adoption of the above detailed conclusion, although revolutionizing to a large extent all that has hitherto been accepted, will prove the only way to place South African geology on a sound and true foundation.

HAARLEM, HOLLAND, *Sept. 21, 1914.* C. G. S. SANDBERG.